CORNELL UNIVERSITY.

Department of Chemistry.

Tetrachlorgallein and Some of Its Derivatives.

A DISSERTATION

Submitted to the University Faculty for the Degree of Doctor of Philosophy.

BY

THOMAS G. DELBRIDGE.

1907.

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ACKNOWLEDGMENT.

This investigation was undertaken at the suggestion of Dr. W. R. Orndorff. With much pleasure I acknowledge my indebtedness to him for his invaluable assistance during the whole of this work, for his many words of encouragement and most of all for his sympathy and interest as my friend.

I desire also to thank Professors Dennis, Chamot and Browne for helpful suggestions and for their uniform kindness to me and Professor Gill for his descriptions of the crystals.

May, 1907.

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[Contributions from the Chemical Laboratory of Cornell University.]

TETRACHLORGALLEIN AND SOME OF ITS DERIVATIVES.

By T. G. Delbridge.

HISTORICAL.

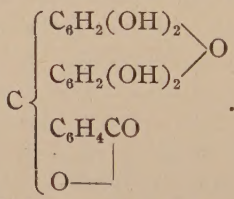
Tetrachlorgallein was first prepared by Graebe[1] in 1887 in the course of his investigation of tetrachlorphthalic acid. It was made by heating tetrachlorphthalic anhydride with pyrogallol to 190°–200°, extracting the mass with hot alcohol, precipitating the tetrachlorgallein with water and again crystallizing it from alcohol. The product thus prepared and purified forms a violet-colored, crystalline powder. Analyses of this substance dried at 100° gave results which agree with the formula $C_{20}H_6O_7Cl_4.2H_2O$, while when dried to constant weight at 180° it had the composition indicated by the formula $C_{20}H_6O_7Cl_4$. These formulas are based on determinations of carbon and hydrogen only and the analytical data are not given, so that it is not possible to recalculate the results. It is quite evident, however, that Graebe assigned this formula to tetrachlorgallein from its analogy to gallein to which Buchka[2] had given the formula $C_{20}H_{10}O_7$

[1] Ann. Chem. (Liebig), **238**, 337 (1887).
[2] *Ibid.*, **209**, 264 (1881).

in 1881. From tetrachlorgallein Graebe obtained a crystalline, almost colorless acetyl compound, which, on analysis, gave him results agreeing approximately with the formula $C_{20}H_4O_7Cl_4(OCCH_3)_4$. This formula is deduced from two determinations of carbon and hydrogen and one of chlorine, no analytical data being given. The percentages of these elements found differ considerably from those required by the theory and it is clear that this formula was assigned to the acetate by Graebe because of its analogy to Buchka's gallein acetate, which has the formula $C_{20}H_8O_7(OCCH_3)_4$. It is but fair to point out that Graebe was studying tetrachlorphthalic acid and some of its derivatives and took up the preparation of tetrachlorgallein only incidentally, so that it is not at all surprising that he confined himself merely to proving that tetrachlorphthalic anhydride combines with pyrogallol to form a compound analogous to gallein.

Since this work of Graebe, no further investigation of tetrachlorgallein has been made.

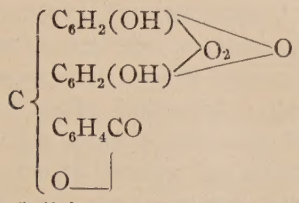
Gallein itself had been previously discovered and studied by Baeyer[1] who regarded it as pyrogallolphthalein anhydride, $C_{20}H_{12}O_7$, analogous to fluorescein, which it closely resembles. The following formula would therefore express its constitution according to Baeyer:



Gallein according to Baeyer.

Later, in 1881, Karl Buchka,[2] working in Baeyer's laboratory, took up the detailed study of gallein and coerulein after Baeyer had determined the structure of phenolphthalein and Emil Fischer that of fluorescein. Buchka assigned to gallein the formula

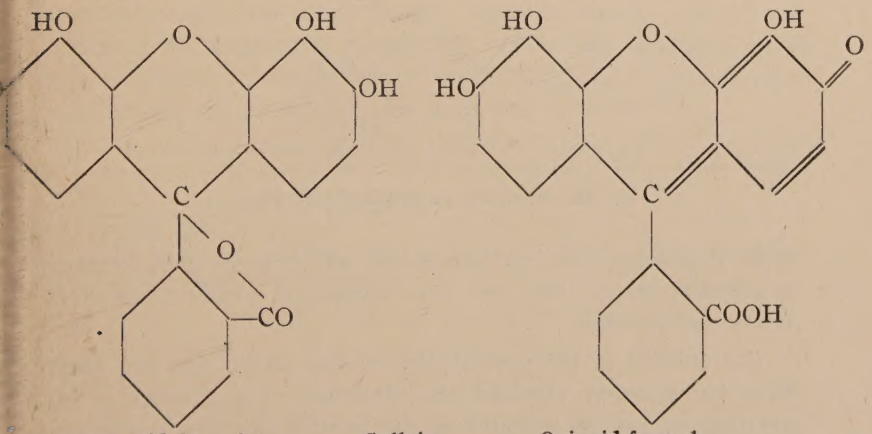
[1] Ber. d. chem. Ges., **4**, 457, 658; Ann. Chem. (Liebig), **202**, 36.
[2] Ann. Chem. (Liebig), **209**, 255 (1881).



Gallein according to Buchka.

assuming that in the formation of this substance two of the hydroxyl groups belonging to the pyrogallol residue are oxidized to a quinone group, analogous to the formation of cedriret by the oxidation of the dimethyl ether of pyrogallol.

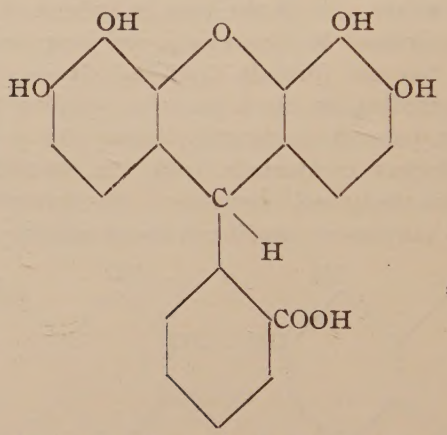
This formula was generally accepted until 1900 when Orndorff and Brewer[1] published the results of their investigation on gallein and coerulein. They found that gallein is not a quinonelike compound as represented in the above formula by Buchka, but is the true anhydride of pyrogallolphthalein, analogous to fluorescein, as first suggested by Baeyer, and has the formula $C_{20}H_{12}O_7$. It is a tautomeric substance, according to these authors, yielding two classes of derivatives, colored compounds having the quinoid structure and colorless compounds with the lactoid structure. Free gallein has the quinoid structure. The following formulas represent the tautomeric modifications of gallein:



Lactoid formula. Gallein. Quinoid formula.

[1] THIS JOURNAL, **23**, 425, and **26**, 97.

In accord with the lactoid formula is the fact that gallein forms a *colorless* tetracetate, *colorless* trimethyl-, triethyl-, tetramethyl- and tetraethyl ethers not saponified by caustic alkalies, and a *colorless* trimethyl ether monacetate. Gallein also forms *colored* mono-esters which are readily saponified and must therefore have the quinoid structure, *colored* tetramethyl- and tetraethyl ethers which give on saponification *colorless* trimethyl- and triethyl ethers and hence must also have the quinoid formula. When heated with phenyl isocyanate, gallein forms a colored triphenylcarbamate having acid properties, thus showing the presence of three phenol hydroxyl groups and a carboxyl group in the molecule. On reduction with zinc dust in acid or alkaline solution, according to Orndorff and Brewer, gallein gives only one product, gallin, to which they assign the formula



Gallin according to Orndorff and Brewer.

since it gives a colorless tetracetate which is an acid forming a colorless silver salt, and also because it yields a colorless pentamethyl ether.

The subject of the constitution of the phthaleins and their salts has recently received the attention of a number of investigators, and on account of the bearing of these researches

on the question of the constitution of tetrachlorgallein the more important papers which have appeared since 1900 are briefly reviewed here.[1]

Nietzki and Schröter[2] had prepared the colored, quinoid carboxyl ester of fluorescein in 1895 by the oxidation of fluorescin ethyl ester. This method is, however, indirect. A direct method of obtaining this ester by heating fluorescein with alcohol and sulphuric acid was discovered in 1901 by Feuerstein and J. Wallach,[3] who thus obtained a colored, quinoid carboxyl ester identical with the one described by Nietzki and Schröter. This colored ester gave a monacetate which was also colored. This work establishes the quinoid formula for the free fluorescein.

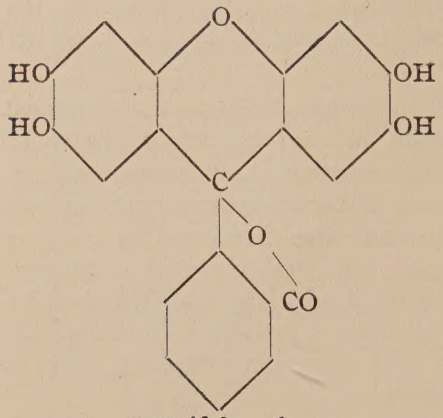
In 1901 three independent investigations[4] were published on oxyhydroquinonephthalein. This substance is isomeric with gallein, and like gallein it is tautomeric, forming colored carboxyl esters which have the quinoid formula and are easily saponified with alkalies, and also a colorless tetracetate which must have the lactoid formula. Like gallein the oxyhydroquinonephthalein is a colored compound and gives colored esters with alcohols and sulphuric acid, hence it must have the quinoid formula. It is a mordant dye, as might have been predicted since it contains two hydroxyl groups in the ortho position to each other. With sulphuric acid it condenses to violein, a compound resembling coerulein made from gallein by the action of sulphuric acid. The tautomeric forms are represented in the following formulas:

[1] For a review of the literature of the phthaleins previous to 1900 the reader is referred to Orndorff and Brewer's article on Gallein and Coerulein, THIS JOURNAL, **26**, 97.

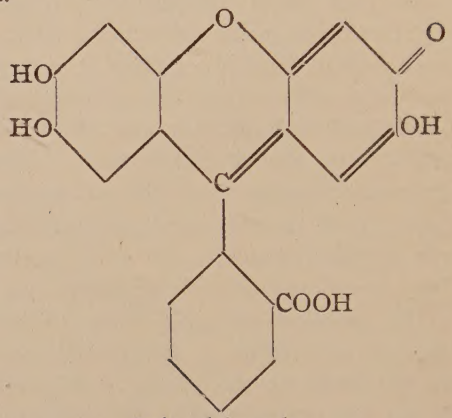
[2] Ber. d. chem. Ges., **28**, 45 (1895).

[3] *Ibid.*, **34**, 2641 (1901).

[4] C. Liebermann: *Ibid.*, **34**, 2299; J. Thiele and C. Jäger: *Ibid.*, **34**, 2617; W. Feuerstein and M. Dutoit: *Ibid.*, **34**, 2637.



Lactoid formula.



Quinoid formula.

Oxyhydroquinonephthalein.

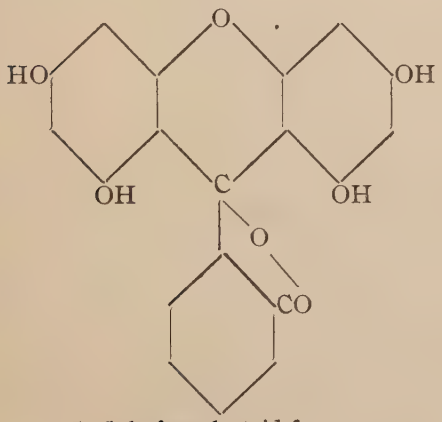
Oxyhydroquinonephthalein dissolves in sodium acetate solution to form a yellowish brown fluorescent solution which becomes fuchsine-red on the addition of alkalies. Only the mono-salts apparently fluoresce.

In 1902 Herzig and Pollak[1] attempted to determine whether the phthaleins in the *free* state have the lactoid or quinoid formula by making use of diazomethane to introduce the alkyl groups. Phenolphthalein gave the lactoid dimethyl ether, fluorescein the quinoid dimethyl ether, hence the first

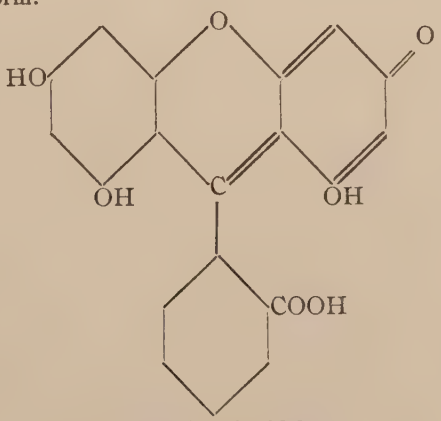
[1] Monatsh. Chem., **23**, 709.

has the lactoid and the second the quinoid formula in the *free* state.

Phloroglucinphthalein was studied in 1903 by C. Liebermann and Th. Zerner.[1] Since the compound crystallized from water in practically colorless needles, the lactoid formula (I) was assumed for it. On drying at 120° this colorless product loses 21 to 25 per cent. of water and becomes orange-yellow. To this form they therefore assign the quinoid formula (II).



I. Colorless, lactoid form.

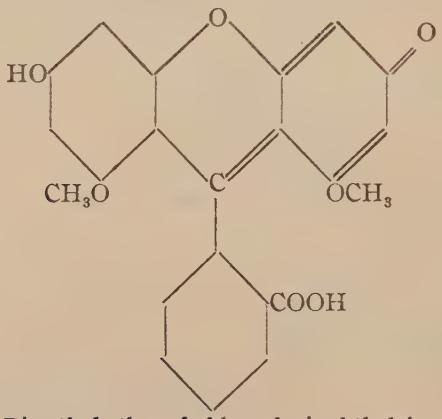


II. Colored, quinoid form.

Phloroglucinphthalein.

[1] Ber. d. chem. Ges., **36**, 1070.

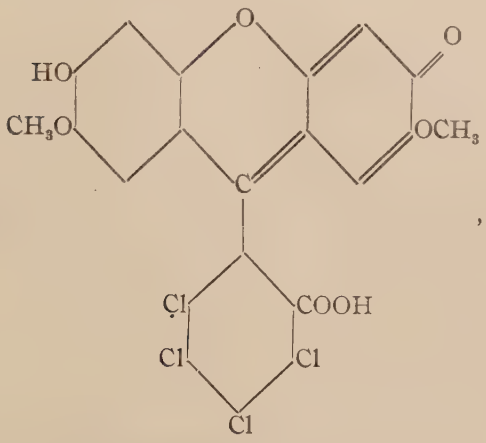
The substance is extremely soluble in alcohol, acetic acid, acetone and boiling water with an orange-yellow color but without fluorescence. Alkalies and the alkaline carbonates dissolve it with a deep orange-red color but these solutions show no fluorescence. A colorless tetracetate and tetrabenzoate were made and also the faintly colored tetrabromphloroglucinphthalein corresponding to eosin. The colored dimethyl ether is soluble in alkalies with an extremely strong yellowish-green fluorescence which may be explained by assuming for the ether in alkaline solution the following formula which shows its analogy with fluorescein:



Dimethyl ether of phloroglucinphthalein.

In 1903 Osorovitz[1] condensed oxyhydroquinone with the halogen substituted phthalic anhydrides. The oxyhydroquinonetetrachlorphthalein forms green crystals with a metallic luster which dissolve in sodium bicarbonate solution with a rose color and greenish fluorescence, whereas in alkalies they dissolve with a red color but without fluorescence. The colored dimethyl ether, however, dissolves in alkalies with a fluorescence resembling that of fluorescein, and its alcoholic solution is also fluorescent. As this dimethyl ether does not color mordants, two free hydroxyl groups in the ortho position are not present and the compound probably has the structure

[1] Ber. d. chem. Ges., **36**, 1076 (1903).



Dimethyl ether of oxyhydroquinonetetrachlorphthalein (colored).

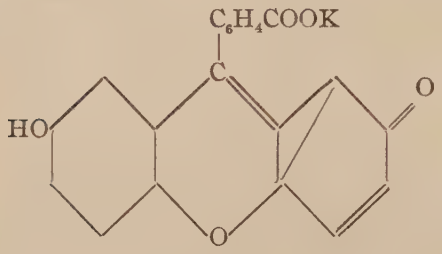
which is in accord with its close resemblance to fluorescein. Osorovitz found that the oxyhydroquinonetetrachlorphthalein does not yield an ester with alcohol and sulphuric acid and suggests that this may be due to the fact that the two ortho positions to the carboxyl group are occupied and therefore, in accordance with the Victor Meyer rule, the compound should not give an ester. All the ethers prepared by Osorovitz were colored and the tetramethyl ether dissolves in alcohol with marked fluorescence similar to that of the dimethyl ether. Oxyhydroquinonetetrachlorphthalein is a tautomeric substance, as it yields a colorless tetracetate, which must have the lactoid formula, in addition to the colored quinoid ethers mentioned above and the red calcium and barium salts. It is isomeric with tetrachlorgallein made by Graebe.

In 1903 R. Meyer and O. Spengler[1] published the results of their investigations on the constitution of the salts of the phthaleins. Meyer[2] had previously determined the structure of hydroquinonephthalein by making dinitrofluoran, converting it into diaminofluoran by reduction, and this into dioxyfluoran by diazotizing and heating with water. This dioxyfluoran, which was identical with hydroquinone-

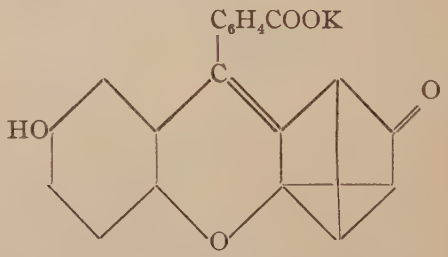
[1] Ber. d. chem. Ges., **36**, 2949.

[2] R. Meyer and H. Meyer: *Ibid.*, **28**, 2559 (1895); R. Meyer and L. Friedland: *Ibid.*, **31**, 1739 (1898).

phthalein, is hence an isomer of fluorescein. It resembles phenolphthalein, however, and not fluorescein in its conduct. In the free state it is colorless but dissolves in alkalies with an intense violet-red color and without fluorescence. The question of the constitution of these colored salts of hydroquinonephthalein presents greater difficulties than in the case of the salts of the other phthaleins, for if they are represented as having the metaquinoid structure, one of the following atomic combinations must be assumed within the molecule:



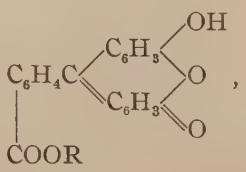
or



Potassium salt of hydroquinonephthalein.

The fact that metaquinones are unknown constitutes, according to Meyer and Spengler, a strong objection to these formulas.

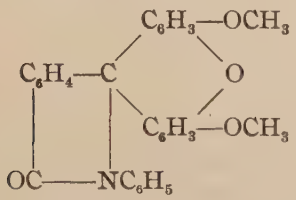
If the hydroquinonephthalein can appear in a quinoid form, then the existence of a carboxyl ester,



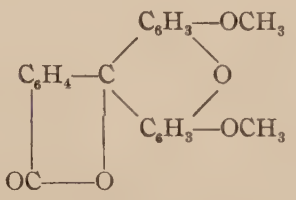
,

is to be expected. Meyer and Spengler tried to make this

ester by first reducing hydroquinonephthalein to the phthalin, converting it into the ester, and then oxidizing this, but no definite product resulted. They also failed to obtain the ester by heating hydroquinonephthalein with alcohol and sulphuric acid. They then investigated the esterification of the hydroquinonephthalein in alkaline solution, but obtained a colorless dimethyl ether, insoluble in alkali, to which they assigned the lactoid formula (II), as the same ether resulted when the anilide of the phthalein was methylated (I) and aniline afterward split off:

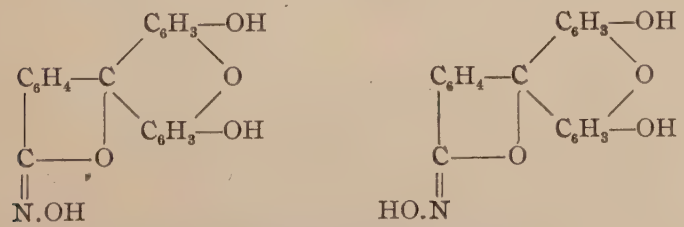


I. Dimethyl ether of hydroquinonephthaleinanilide.



II. Dimethyl ether of hydroquinonephthalein.

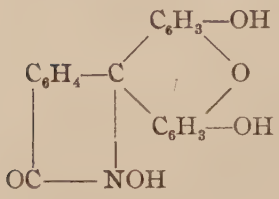
They then took up the action of hydroxylamine on an alkaline solution of hydroquinonephthalein and found that three oximes are formed. The main product (α) is colorless and dissolves in alkalies without color and without fluorescence, the two others (β and γ), formed in much smaller quantity, are yellowish-brown. One of them (β) dissolves in methyl alcohol with an intense greenish fluorescence and may be converted into the compound (γ), which does not fluoresce, from which it may be assumed that these two oximes are stereoisomeric. In later articles[1] they give the following stereo formulas for these two oximes:



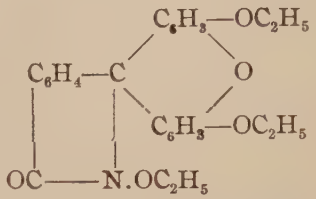
β- and γ-Hydroquinonephthalein oximes.

[1] Ber. d. chem. Ges., **38**, 1318 and **42**, 2825.

The α-oxime was converted in alkaline solution into the colorless *triethyl ether insoluble in alkalies.* They therefore assign the following formulas to these compounds:

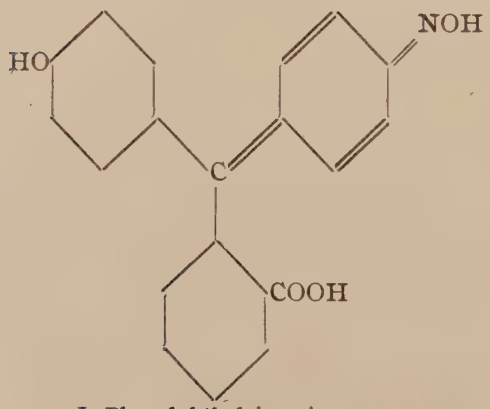


Hydroquinonephthalein α-oxime.



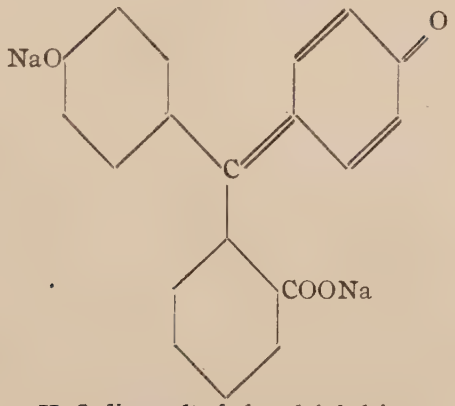
Triethyl ether of hydroquinonephthalein α-oxime.

They then undertook a study of the yellow phenolphthalein oxime, first prepared by Friedländer[1] by treating an alkaline solution of phenolphthalein with hydroxylamine hydrochloride. To this yellow compound Friedländer gave the formula (I):



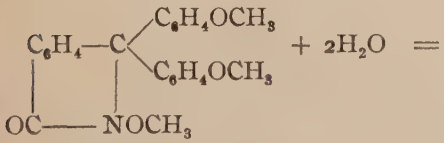
I. Phenolphthalein oxime.

[1] Ber. d. chem. Ges., **26**, 172 and 2258.

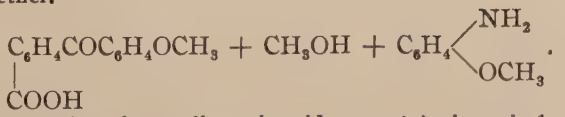


II. Sodium salt of phenolphthalein.

The formation of this colored oxime was at first considered an important confirmation of the quinoid formula of the salts of phenolphthalein (II). Meyer and Spengler show that the oxime forms a practically colorless trimethyl ether when its strongly alkaline solution is shaken with dimethyl sulphate and that this trimethyl ether undergoes saponification with alcoholic caustic potash, yielding a colorless dimethyl ether of the oxime soluble in acids as well as in alkalies. With acids the trimethyl ether splits up into *p*-methoxybenzoylbenzoic acid, methyl alcohol and *p*-aminoanisol, as shown in the following equation:

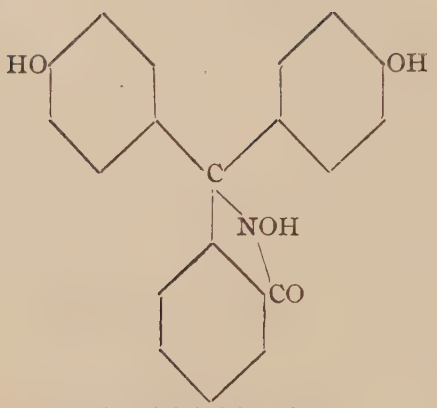


Phenolphthalein oxime trimethyl ether.

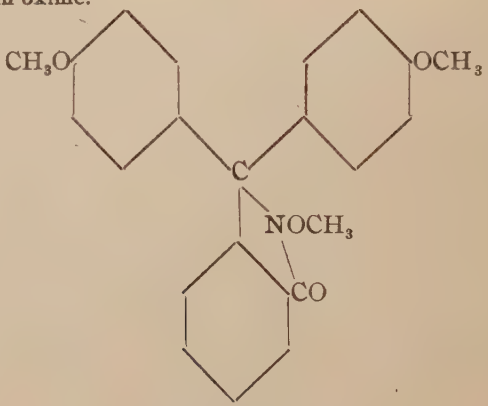


***p*-Methoxybenzoylbenzoic acid.** ***p*-Aminoanisol.**

From these facts it follows that in phenolphthalein oxime there are still present *two* phenol hydroxyl groups. They therefore give the following formulas to the oxime and its trimethyl ether:



Phenolphthalein oxime.



The trimethyl ether.

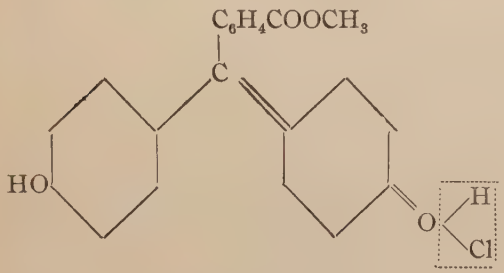
They conclude that, contrary to the generally accepted view, the colored salts of the phthaleins are not quinoid but lactoid in structure and they uphold this view in a later article.[1]

Baeyer,[2] after a thorough study of the colored saltlike compounds of triphenylcarbinol, concludes that they do not contain a quinoid group and he approves of the view of Meyer and Spengler that, from the closely agreeing conduct of hydroquinonephthalein and phenolphthalein, the colored salts of these substances also do not contain a quinoid group. He applies his theory of the carbonium isomerism to the phthaleins

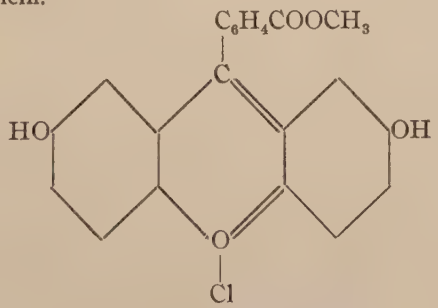
[1] Ber. d. chem. Ges., **38**, 1318 (1905).
[2] *Ibid.*, **38**, 569 (1905).

and gives formulas for the sodium salts of phenol- and hydroquinonephthaleins, representing them as containing an ionizable carbonium valence which he regards as the cause of color in these salts. As Baeyer[1] has now abandoned this theory, no further mention of it need be made here.

The views of Meyer and Spengler concerning the constitution of phenol- and hydroquinonephthalein salts were disproved by Green and King[2] who succeeded in making colored quinoid esters of these two phthaleins. Nietzki and Burckhardt[3] had previously prepared colored quinoid esters of tetrabromphenolphthalein by oxidation of the esters of tetrabromphenolphthalin. This method is, however, so indirect that it can hardly be regarded as a proof of the tautomerism of phenol- and hydroquinonephthalein. Green and King prepared their esters in the form of chlorides, by dissolving the phthaleins in methyl alcohol and passing in hydrochloric acid gas. They give to the chlorides of the two phthalein methyl esters the following formulas:



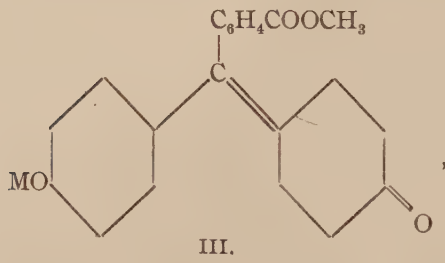
I. Hydrochloride of the methyl ester of phenolphthalein.



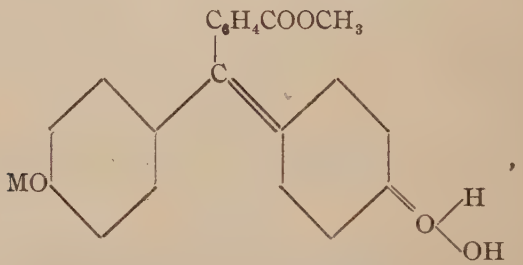
II. Chloride of the methyl ester of hydroquinonephthalein.

[1] Ann. Chem. (Liebig), **354**, 152 (1907). See also Ber. d. chem. Ges., **42**, 2624.
[2] Ber. d. chem. Ges., **39**, 2365 (1906) and **40**, 3724 (1907).
[3] *Ibid.*, **30**, 175 (1897).

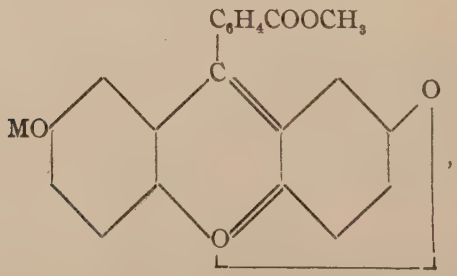
Hydrochloric acid can be split off the hydrochloride of the methyl ester of phenolphthalein (I) with ammonia and an orange-red ester is obtained which is more stable than the hydrochloride. The hydroquinonephthalein ester could not be obtained in the free state as it is very unstable. Its chloride (II) is, however, more stable. Contrary to expectations these esters dissolve in alkalies without saponification with a violet-red color. To these salts they give the formulas



III.



IV. Metallic salt of the methyl ester of phenolphthalein.



V. Metallic salt of the methyl ester of hydroquinonephthalein.

in which M represents the metal. Formula IV is given the preference over III as it brings out better the resemblance

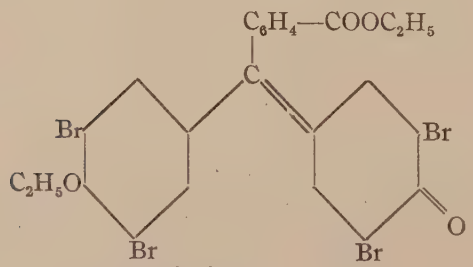
which exists between both classes of salts. They give to the colored metallic salts of phenolphthalein and hydroquinonephthalein, in which the resemblance in color points to an analogy in structure, similar formulas, simply replacing the methyl group by the metal. They conclude that the differences between phenol- and hydroquinonephthalein on the one hand and fluorescein on the other are only of degree. In all three the phenomenon of tautomerism is shown; while, however, the peculiar grouping in the two first named phthaleins is the lactoid form, that of fluorescein appears to be the quinoid. The cause of the color is the same in all three.

A. Hantzsch,[1] in his work on the isomerism of the nitrophenol salts and the existence of metaquinoid compounds, has called attention to the fact that the salts of the colorless *m*-nitrophenol can be obtained in two distinct modifications, one red and the other yellow. Hence in the formation of colored salts from the colorless mother substance an intramolecular rearrangement must also be assumed to take place in the meta series. This fact furnishes a direct proof of the existence of metaquinoid compounds, against the assumption of which much has been said even very recently. For even if one of the two *m*-nitrophenol salts is regarded as a normal nitrophenol salt (notwithstanding its marked color), still, on account of the existence of the second isomer, the assumption of an isomerized nitrophenol salt is unavoidable. Hence, according to Hantzsch, there certainly exists also in the meta series of compounds the same atomic rearrangement as he has proved to exist in the ortho and para series (*e. g.*, in the case of the aniline dyestuffs) and which he has designated as quinoid transformations. In answer to the objection against the assumption of such metaquinoid salts that simple metaquinones or their derivatives (quinoneimides, quinone-oximes) are not known and perhaps are really not capable of existence, Hantzsch points out that there is a difference between metaquinones and metaquinoid salts which may explain the existence of the latter in spite of the nonexistence of the former. The metaquinones should be

[1] Ber. d. chem. Ges., **40**, 339.

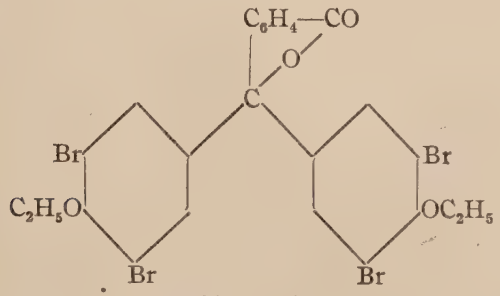
indifferent, electrically neutral compounds. The metaquinoid salts are formed from the colorless hydrogen compounds by the action of a positive metal, which isomerizes the nitrophenols to quinoid derivatives of nitric acid, or these salts exist in solution as ions, *i. e.*, as electrically charged complexes. Hence in all probability the metaquinoid condition can only be made stable in the case of electrolytes under the compulsion of a positive metal (or negative radical) or by taking up electric charges. By making these metaquinoid nitrophenol salts, Hantzsch removed the last objection to the metaquinoid formula for the salts of hydroquinonephthalein.

R. Meyer and K. Marx,[1] in commenting on the work of Green and King, call attention to the fact that these chemists made their esters from the phthaleins themselves by acid alkylation and not from the salts of the phthaleins and, on this account, they say that even this valuable result can not be regarded as a certain proof of the quinoid nature of the phthalein salts. They also call attention to the fact that Hantzsch did not work with the phthaleins but extends his conclusions drawn from the nitrophenols to these substances. They therefore endeavored to make the quinoid esters directly from the silver salt of the phthalein according to the method used by Hantzsch in making his ethers of the nitrophenols. By treating the *blue* disilver salt of tetrabromphenolphthalein suspended in dry benzene with dry ethyl iodide, they obtained the yellow, quinoid diethyl ether of tetrabromphenolphthalein, identical with the compound previously prepared by Nietzki and Burckhardt, to which they give the following formula (I):



I. Quinoid ether (colored).

[1] Ber. d. chem. Ges., **40**, 1437.



II. Lactoid ether (colorless).
Diethyl ether of tetrabromphenolphthalein.

This colored ether (I) changes over with the greatest ease into the colorless lactoid ether (II) (just as is the case with Hantzsch's quinoid nitrophenol ether), so that it was impossible for them to obtain it entirely free from its isomer, which was also plainly the case with Nietzki and Burckhardt. R. Meyer and Marx thus prepared a quinoid phenolphthalein derivative directly from a phthalein salt. This, according to them, had never been previously accomplished.[1] Later R. Meyer and Marx[2] prepared the diethyl ether ester of phenolphthalein itself from the solid dipotassium salt and found that it is intensely yellow and changes on recrystallizing into the stable, colorless lactone di-ether. They also studied the absorption spectra of the alkali salts of phenolphthalein, hydroquinonephthalein and fluorescein in neutral aqueous solution and found that while the spectra of the three phthaleins at approximately the same concentration and also the colors of their solutions have a very different appearance, the curves which are obtained when the wave lengths of the absorbed light are represented as functions of the concentration are exactly alike.

K. H. Meyer and A. Hantzsch[3] investigated the salts of phenolphthalein and its lactoid and quinoid ethers with acids. The red sulphate of phenolphthalein they could not obtain in crystalline form nor could they isolate a hydrochloride of definite composition. It was shown that phenolphthalein

[1] In 1901 Orndorff and Brewer prepared colored quinoid ethers of gallein from the alkali salts with alkyl iodides. See THIS JOURNAL, **26**, 137.

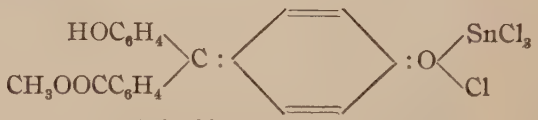
[2] Ber. d. chem. Ges., **40**, 3603.

[3] *Ibid.*, **40**, 3479.

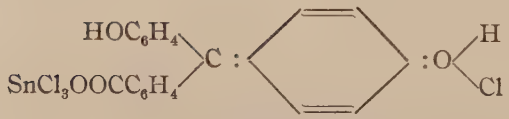
took up hydrochloric acid at —30°, at the same time turning red. On warming, this compound was decolorized and lost all of the absorbed acid. With aluminum chloride and tin tetrachloride, however, phenolphthalein forms beautiful red double salts of the formulas $C_{20}H_{14}O_4AlCl_3$ and $C_{20}H_{14}O_4SnCl_4$. These double salts are, according to Straus,[1] A. Werner,[2] and others, perfectly analogous to the colored salts with the inorganic acids. The lactoid dimethyl ether of phenolphthalein and also the quinoid monomethyl ester of Green and King form similar colored salts and the absorption spectra are practically the same. This leads to the conclusion, according to K. H. Meyer and Hantzsch, that all the acid salts of the phenolphthalein group are quinoid. They give the following formulas to the tin chloride double salts:

Tin tetrachloride double salts with

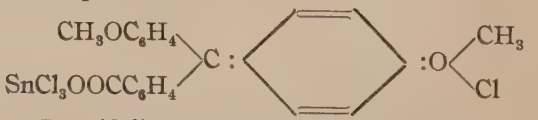
Benzaurin.



Quinoid ester of phenolphthalein.



Phenolphthalein.

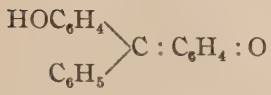


Lactoid dimethyl ether of phenolphthalein.

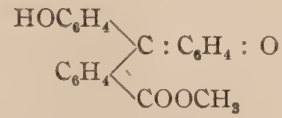
They also call attention to the close resemblance of benzaurin and the quinoid ester of phenolphthalein, as shown in the following formulas:

[1] Ber. d. chem. Ges., **37**, 3277.

[2] Neuere Anschauungen auf dem Gebiete der anorgan. Chemie, S. 91.



I. Benzaurin.



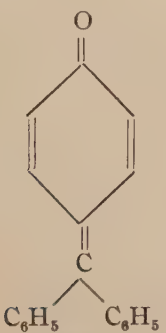
II. Quinoid phenolphthalein ester.

The ester (II) forms red-violet alkali salts, just as benzaurin and phenolphthalein do. Since the alkali salts of phenolphthalein have the same color as those of its quinoid ester we must, according to these authors, also assign the quinoid formula to them. This is in harmony with the observation of Nietzki and Burckhardt[1] that their quinoid tetrabromphenolphthalein ethyl ester forms *blue* alkali salts.

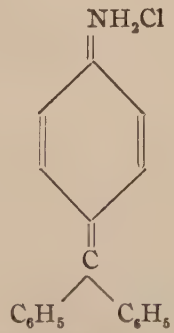
After a very thorough investigation of the derivatives of triphenylcarbinol Baeyer[2] draws the following conclusions concerning the connection between color and chemical composition in the case of those compounds containing only one oxy or amino group in each benzene ring:[3]

1. All carbinols are colorless. Color only appears in consequence of the elimination of water from the molecule.

2. Only the para monosubstitution products are capable of losing water. From the *p*-oxytriphenylcarbinol the orange-colored fuchsone is obtained, while the hydrochloric acid salt of *p*-aminotriphenylcarbinol gives the like colored fuchsonimonium chloride:



Fuchsone.



Fuchsonimonium chloride.

[1] Ber. d. chem. Ges., **30**, 175 (1897).

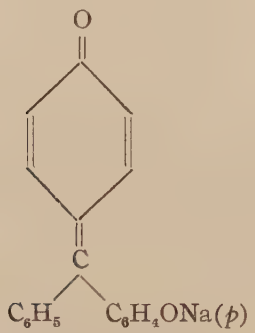
[2] Ann. Chem. (Liebig), **354**, 152.

[3] Derivatives of triphenylcarbinol containing only one oxy or amino group in each benzene ring Baeyer designates as singular, those containing two groups as binary, and those containing three as ternary.

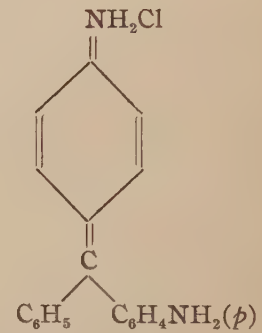
3. The singular[1] disubstitution products of the oxygen series and of the nitrogen series conduct themselves differently.

a. Only those oxygen compounds lose a molecule of water which contain at least one oxy group in the para position. There are thus formed *p*-, *o*- or *m*-oxyfuchsones exactly analogous to fuchsone. In alkalies all three dissolve with intense color, violet, bluish red, and blood-red. Only the *p*-*p'*-form is stable in alkaline solution and only this solution shows a characteristic spectrum—the spectrum of benzaurin.

b. The hydrochloric acid salts of the singular diaminotriphenylcarbinols resemble the alkaline salts of the oxyfuchsones in that only the *p*-*p'*-form (Doebner's violet) gives a characteristic spectrum identical with the benzaurin spectrum:



Sodium salt of benzaurin.

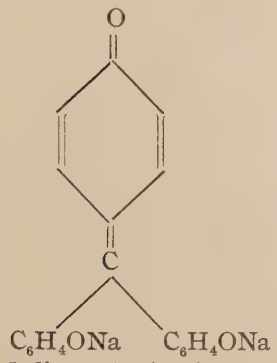


Doebner's violet.

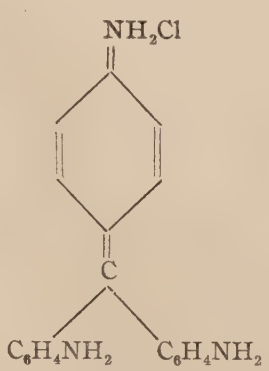
The *p*-*m'*-compound conducts itself like the mono-*p*-amino-compound and in the *p*-*o'*-form the tinctorial effect of the *p*-amino group is actually diminished. The forms containing no *p*-amino groups do not give the slightest color in acid solution.

4. Of the singular trisubstitution products only aurin is known in the oxygen series and this gives in alkaline solution a characteristic spectrum very much like that of benzaurin:

[1] See foot-note 3 on page 203.



Sodium salt of aurin.



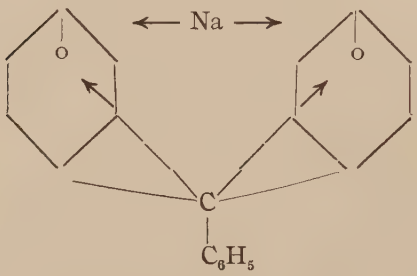
Parafuchsine.

Parafuchsine, in the nitrogen series, corresponds to aurin and its solution shows the same spectrum as the alkaline aurin solution. The condition necessary for the formation of a colored salt is the presence of two amino groups in the para position as is shown by *o*-aminomalachite green, which contains only two amino groups in the para position. All the other triaminotriphenylcarbinols dissolve in acids either quite without color or at most with an orange-yellow color.

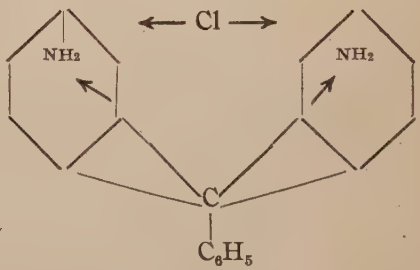
5. The total result is, therefore, that at least two oxy or amino groups must be present in the para position in order to bring about the characteristic spectrum, a sharply bordered narrow band. The typical substances are therefore the sodium salt of benzaurin and Doebner's violet on the one hand, and the sodium salt of aurin and *p*-fuchsine on the other.

Baeyer then attempts an explanation of the color of the aniline and aurin dyestuffs as follows: the formation of the aniline dyes is due to the presence of at least two amino groups in the para position. We may also formulate this as follows: If we designate in the diaminotriphenylcarbinol the amino-benzene rings by *a* and *b*, then it is immaterial whether *a* or *b* goes over into the quinoid form and the quinoid form *a* can go over into the quinoid form *b* without changing the nature of the substance. It is conceivable, therefore, that a continuous oscillation takes place which may give rise to rhythmic ether vibrations of a definite wave length and thus

produce a characteristic spectrum. The same reasoning holds for the sodium salt of benzaurin. It might be urged against this theory that the transformation of an aniline residue into a quinoid group is such a complicated process that the rapid repetition of the same can scarcely be assumed to take place, especially in the solid dyestuff. This objection disappears, however, if we return to the old Graebe quinone formula for the methylenequinone, which was first suggested for fuchsine by Emil and Otto Fischer and which has not yet been proved to be incorrect. The following figures, in which the long arrows indicate the fourth valence of the central carbon atom oscillating to and fro, show plainly that the process may be referred to a simple vibration of the central carbon atom, since the oscillation of the sodium or the chlorine ion to and fro does not introduce the slightest difficulty, according to the electrolytic dissociation theory:



Sodium salt of benzaurin.



Doebner's violet.

The same reasoning holds for the sodium salt of aurin and for *p*-fuchsine, in which the oscillation in three benzene rings takes place.

This review outlines the most recent work on the phthaleins. Tetrachlorgallein was chosen as the subject of this investigation for the following reasons:

1. In order to test the correctness of the formula assigned to gallein by Orndorff and Brewer.[1]

2. To study the effect upon the phthaleins of introducing negative groups into the phthalic acid radical.

3. To throw additional light on the subject of the phthaleins in general.

4. To study the relation between color and constitution in these compounds and to determine the cause of the color.

EXPERIMENTAL.

The pyrogallol used in this investigation was obtained from Kahlbaum. It was perfectly white, melted at 131°–132° (uncor.),[2] and left no residue on ignition. It dissolved in ether and in alcohol without color and the aqueous solution was only faintly pink. The tetrachlorphthalic anhydride used was prepared by heating tetrachlorphthalic acid for about thirty hours at 105°, the acid having been carefully purified by the method already described.[3]

Tetrachlorgallein.

This compound was first prepared according to the directions of Graebe[4] by heating tetrachlorphthalic anhydride with pyrogallol at 190°–200°. The product obtained in this way was so impure and the yield so small that this method was abandoned. Freshly fused and powdered zinc chloride proved to be an extremely efficient condensing agent and its use is indispensable in obtaining a high yield of the tetrachlorgallein. After many experiments, the following method of preparation was finally adopted: 286 grams (1 molecule) of pure tetrachlorphthalic anhydride and 265 grams (2.1 molecules) of pyrogallol were *thoroughly* mixed by grinding and sifting, transferred to a two-liter balloon flask contain-

[1] This Journal, **26**, 137.

[2] The melting points given in this paper were taken with a thermometer compared with one standardized by the Physikalisch-technisches Reichsanstalt.

[3] Delbridge: This Journal, **41**, 403.

[4] Ann. Chem. (Liebig), **238**, 337 (1887).

ing 137 grams (0.5 molecule) of *finely* powdered zinc chloride, and the mixture made as intimate as possible by stirring and shaking. The flask, closed by a perforated cork carrying a loosely fitting thermometer, was half immersed in a bath of concentrated sulphuric acid whose temperature was kept at 200°–210° throughout the whole operation. The contents of the flask melted at 130°–140° to a viscous, reddish colored liquid which was kept well stirred with the thermometer. Steam soon filled the flask, driving out the air and thus preventing oxidation of the tetrachlorgallein and of the pyrogallol. The temperature rose rapidly to 175° and a vigorous reaction took place, marked by frothing and the evolution of much steam. The temperature remained constant at 175°–176° for about thirty minutes and then rose slowly to 190°, the melt becoming more viscous and darker colored. After the mass had been heated for thirty minutes longer at 190°–195°, it became almost solid and the flask was removed from the bath, filled with carbon dioxide, allowed to cool, and then broken. The hard, greenish colored reaction product was separated from the broken glass, ground in a mill, and the resulting dark brown powder kept in tightly stoppered bottles.

The removal of zinc chloride was accomplished in two ways. In the earlier part of the investigation, the powdered reaction product was extracted with boiling two per cent. hydrochloric acid until the extract no longer contained zinc, and the residue, after thorough washing with water, was dried at room temperature. The crude tetrachlorgallein obtained in this way was a reddish brown powder which dissolved completely in sodium hydroxide and in acetone, a fact which showed that no carbonaceous matter had been formed in its preparation. The water in this product was determined by drying to constant weight in an atmosphere of carbon dioxide at 157° (cumene), using the apparatus already described.[1] It was found in the beginning of this investigation that tetrachlorgallein and many of its derivatives are very readily oxidized in the air even at comparatively low

[1] Delbridge: This Journal, **41**, 403.

temperatures. In this respect these compounds resemble pyrogallol, of which they are really derivatives. For this reason the apparatus above mentioned was used in *all* cases where these compounds were heated. Without some such device it would have been impossible to obtain many of the results given in this paper.

Substance. Gram.	Loss. Gram.	Water. Per cent.
0.5559	0.0210	3.78
0.6297	0.0241	3.83
Calculated[1] for $C_{20}H_8O_7Cl_4.H_2O$,		3.47

Chlorine in this product dried at 157° was determined by the modification of the lime method described in another paper.[2] 0.2559 gram of the substance required 20.37 cc. of tenth-normal silver nitrate solution.

	Calculated for $C_{20}H_8O_7Cl_4$.	Found.
Cl	28.26	28.23

This product was not pure tetrachlorgallein hydrate, however, as it was found to contain a small amount of tarry, noncrystallizable impurities which gave a dirty red color with caustic alkali solution.

In the latter part of the investigation the removal of zinc chloride was effected by a method which made it possible to separate the crude product into two fractions, one of which was almost pure. The finely ground reaction product obtained in the preparation of the compound was shaken for several minutes with an equal weight of *cold* methyl alcohol and the undissolved material filtered off and washed with cold methyl alcohol until it was free from zinc. This residue had a light salmon color and was found to be practically pure tetrachlorgallein. The methyl alcoholic filtrate was strongly acidified with hydrochloric acid and diluted with ten times its volume of water to precipitate all the tetrachlorgallein. The precipitate was thoroughly washed with hot water and dried at room temperature. It had a dark brown color and

[1] International Atomic Weights for 1909 have been used in all calculations.

[2] Delbridge: "Tetrachlorphthalic Acid," THIS JOURNAL, **41**, 393.

contained impurities giving a dirty red color with sodium hydroxide solution. This impure fraction constituted about 18 per cent. of the total crude product obtained by the methyl alcohol purification, and the remaining 82 per cent. was practically pure, as stated above.

The average yield of crude tetrachlorgallein was about 83 per cent. of the theoretical, as shown in the following table:

	Tetrachlorphthalic anhydride. Grams.	Crude tetrachlorgallein. Grams.	Yield of $C_{20}H_8O_7Cl_4.H_2O$. Per cent.
I	286	430	83
II	278	427	84
III	715	1102	85
IV	715	1062	82

Zinc chloride was removed from IV by the methyl alcohol treatment, but from the others by extraction with hot dilute hydrochloric acid.

Pure tetrachlorgallein was prepared from this crude product by repeated crystallization from methyl alcohol. The compound was thus obtained in reddish brown, granular crystals containing varying amounts of alcohol and water. These crystals were dried to constant weight at 157° in an atmosphere of carbon dioxide in the apparatus to which reference has been made above.[1] Determinations of chlorine in this dried material gave the following results:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2908	23.05	28.11
0.2621	20.84	28.19
0.2629	20.89	28.18
Calculated for $C_{20}H_8O_7Cl_4$,		28.26

This anhydrous tetrachlorgallein has only a faint reddish color. It is practically insoluble in water, benzene, chloroform, ether, ligroin and carbon bisulphide. In alcohol, acetone, acetic acid and ethyl acetate it dissolves with a faint red color which becomes deep red on the addition of a little water. Tetrachlorgallein is much more soluble in

[1] Page 208.

methyl alcohol than in ethyl alcohol and the crystals from the former contain methyl alcohol. Solutions of sodium and potassium hydroxides dissolve tetrachlorgallein with an intense blue color, while the solution in ammonia is bluish purple. Solutions of the alkali carbonates and bicarbonates dissolve tetrachlorgallein in the cold, carbon dioxide being evolved. The color of the solution is claret-red when an excess of the phthalein is present, but deep purple with an excess of the carbonate. This fact indicates that there are at least two series of alkali salts, one dissolving with a red color and the other with a purple color. Solutions of sodium acetate and borax dissolve tetrachlorgallein with a reddish purple color. From the *freshly* prepared alkaline solutions, acids precipitate tetrachlorgallein hydrate in red microscopic crystals, but if the alkaline solution is allowed to stand in the air it is rapidly oxidized and turns yellow, and acids then give no precipitate.

Tetrachlorgallein differs from gallein in that it is practically insoluble in an aqueous solution of pyrogallol and also in a solution of hydrochloric acid (sp. gr. 1.1). Gallein dissolves readily in this hydrochloric acid and if the hot solution be filtered gallein hydrochloride crystallizes out of the filtrate in beautiful needle-shaped crystals, red by transmitted light and green in reflected light. Gallein is therefore much more basic than tetrachlorgallein.

When tetrachlorgallein is exposed to ammonia gas it turns red at once and then almost black, forming an ammonium salt which dissolves in water with a bluish purple color. Dry hydrochloric acid gas also combines with solid tetrachlorgallein, forming a dark red hydrochloride which is decomposed by heat or by water. The aluminum salt of tetrachlorgallein has a violet color, the copper and iron salts are purple, and the lead and barium salts are dark blue. These salts are all only slightly soluble in water. A number of attempts were made to prepare a silver salt of tetrachlorgallein but metallic silver was formed in every case, a further indication of the ease with which this phthalein is oxidized.

Heated to 320° tetrachlorgallein does not melt but gives

off hydrochloric acid slowly even below this temperature, while at higher temperatures it yields a reddish colored sublimate whose nature was not investigated.

The color of crystallized tetrachlorgallein varies, with the conditions of crystallization, from faint pink to a deep red, so that color gives no reliable indication as to the purity of the product. An easy method for testing the purity of the compound consists in boiling a little of it with acetic anhydride for about five minutes. Pure tetrachlorgallein gives a pale lemon-colored solution, the presence of impurities being denoted by a red or brown color. The various forms of tetrachlorgallein are being further investigated and a colorless modification has been prepared, probably a carbinolcarboxylic acid.

Tetrachlorgallein Hydrochloride.

This compound was prepared by passing dry hydrochloric acid gas into a cooled solution of ten grams of pure tetrachlorgallein in 150 cc. of dry acetone. The precipitate which separated was filtered off, washed with a little dry acetone, and kept over sulphuric acid. The product thus obtained consisted of small prismatic crystals, red to transmitted light but green to reflected light. The green luster is destroyed by grinding or by exposure to moist air. A weighed portion of the compound was placed in a platinum boat and heated in the drying apparatus to 157° (cumene) in a current of hydrogen. The outflowing gases were passed through cold water in a Hugershoff gas washing bottle with flat glass spiral, and the amount of hydrochloric acid given off was determined by titration with tenth-normal sodium hydroxide solution, phenoltetrachlorphthalein[1] being used as indicator. The substance left in the boat was then weighed and it was found that the total loss of weight was much greater than the weight of hydrochloric acid found on titration. This difference was due to loss of acetone, identified by its odor, by conversion into iodoform, and by the formation of acetone phenylhydrazone. The residue left in the boat had a faint pink

[1] Orndorff and Black: This Journal, **41**, 349; Delbridge: *Ibid.*, **41**, 401.

color and gave all the reactions of tetrachlorgallein. Chlorine in this residue was determined with the following results:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2597	20.51	28.01
0.3009	23.82	28.07
Calculated for $C_{20}H_8O_7Cl_4$,		28.26

On account of the fact that the hydrochloride contained some acetone of crystallization, the hydrochloric acid found on titration is expressed as grams of hydrochloric acid per hundred grams of tetrachlorgallein.

Tetrachlorgallein left in boat. Gram.	Tenth-normal sodium hydroxide. cc.	Hydrochloric acid. Grams per 100.
0.1851	3.43	6.76
0.3014	5.78	6.99
Calculated for $C_{20}H_8O_7Cl_4.HCl$,		7.27

The difference between the hydrochloric acid found and the calculated amount is due to the fact that the product had lost a little hydrochloric acid before the analysis was made. It is evident, however, that this compound is a *mono*-hydrochloride with acetone of crystallization.[1] This hydrochloride is decomposed quantitatively by hot water and the hydrochloric acid liberated may be determined by direct titration with tenth-normal sodium hydroxide solution, the tetrachlorgallein serving as the indicator. Analyses:

Substance. Gram.	Anhydrous tetrachlorgallein. Gram.	Tenth-normal sodium hydroxide. cc.	Hydrochloric acid. Grams per 100.
0.5335	0.4897	9.35	6.96
0.5028	0.4616	8.80	6.95
0.5335	0.4897	9.39	6.99
Calculated for $C_{20}H_8O_7Cl_4.HCl$,			7.27

Monosodium Salt of Tetrachlorgallein.

For the preparation of this compound 20 grams of tetrachlorgallein were suspended in three liters of boiling water in a five-liter balloon flask, and the mixture was kept boil-

[1] Heller and Langkopf have prepared a "Salzsaures Galleinacetonat" to which they give the formula $C_{20}H_{12}O_7$; $HCl.C_3H_6O$ (Z. Farb. Ind., **5**, 115).

ing vigorously while a solution of 1.5 grams of pure anhydrous sodium carbonate in 100 cc. of water were added gradually. The solution became claret-red at once and carbon dioxide was evolved. After the mixture had been boiled vigorously for thirty minutes, the excess of tetrachlorgallein was filtered off as rapidly as possible, the solution filtered again, and the filtrate concentrated to about 900 cc. by distillation in a flask. Evaporating dishes could not be used for this purpose because the hot solution is too easily oxidized by the air. The deep red solution was allowed to stand for two days and the dark colored crystalline substance which separated was filtered off, washed with cold water, and dried to constant weight at room temperature. A number of attempts were made to determine the water of crystallization in this product by drying at various temperatures in a Victor Meyer oven but the loss of weight was continuous and it was found that the salt is oxidized in the air at temperatures above 100°. It was this difficulty which led to the construction of the drying apparatus described in another paper.[1] Water of crystallization in the sodium salt was finally determined in this apparatus by drying to constant weight in a current of carbon dioxide at 160° (cumene).

Substance. Gram.	Loss. Gram.	Water. Per cent.
0.3155	0.0407	12.90
0.1967	0.0254	12.91
Calculated for $C_{20}H_7O_7Cl_4Na.4H_2O$,		12.09

On drying to constant weight *in vacuo* over phosphorus pentoxide, results were obtained which indicate that the sodium salt retains a half molecule of water under these conditions.

Chlorine and sodium were determined in the compound dried to constant weight at 160°:

Substance. Gram.	Silver chloride. Gram.	Chlorine. Per cent.
0.2158	0.2348	26.92
0.2028	0.2202	26.86
Calculated for $C_{20}H_7O_7Cl_4Na$,		27.07

[1] This Journal, **41**, 403.

Substance. Gram.	Sodium sulphate. Gram.	Sodium. Per cent.
0.2455	0.0311	4.10
0.3054	0.0391	4.15
Calculated for $C_{20}H_7O_7Cl_4Na$,		4.39

These analyses, together with the method of preparation, show clearly that the compound is the monosodium salt of tetrachlorgallein. The air-dried material is almost black and has a bronzy luster. The crystals were too small for a crystallographic examination but appear under the microscope as slender prisms showing a marked tendency to felt together. The dried salt has a red color. The compound dissolves in water with a claret-red color, but partial hydrolysis takes place and some tetrachlorgallein is precipitated. There is a possibility, therefore, that the sodium salt made in aqueous solution contains traces of tetrachlorgallein, and in order to overcome this objection a sodium salt was prepared by the following method:

Pure anhydrous tetrachlorgallein (16.4 grams) was dissolved in a mixture of 250 cc. of acetone and 500 cc. of 94 per cent. ethyl alcohol, both freshly distilled. This solution was filtered and kept boiling vigorously in a flask connected with a return condenser while a filtered solution of 4.2 grams of pure crystallized sodium acetate in 100 cc. of 94 per cent. alcohol was added rather slowly through the condenser. A heavy, dark colored precipitate was formed and after the mixture had been boiled for twenty minutes this precipitate was filtered off with suction, washed thoroughly with hot acetone to remove the last traces of tetrachlorgallein, and dried to constant weight at room temperature. The sodium salt obtained in this way was beautifully crystallized, consisting of slender transparent prisms which had a brownish black color with a bronzy luster. Like the sodium salt made in aqueous solution this compound dissolved in water with a claret-red color and was partially hydrolyzed, some tetrachlorgallein being precipitated. The substance was dried to constant weight in carbon dioxide at 157° (cumene) and then analyzed for sodium and chlorine. The sodium was

determined by conversion into sodium sulphate and also by a much more rapid volumetric method conducted in the following manner: A weighed portion of the salt was suspended in 200 cc. of cold water in a porcelain dish and a measured excess of tenth-normal hydrochloric acid solution added at once. The mixture was heated on a steam bath for a few minutes to insure complete decomposition of the sodium salt and then titrated with tenth-normal sodium hydroxide solution. The tetrachlorgallein served as a delicate indicator, the slightest excess of alkali being denoted by a rose-red color. Analyses:

Substance. Gram.	Sodium sulphate. Gram.	Tenth-normal hydrochloric acid. cc.	Sodium. Per cent.
0.6101	0.0794	.....	4.21
0.4555	0.0596	.....	4.24
0.9894	.....	18.28	4.25
1.1089	.....	20.54	4.26
	Calculated for $C_{20}H_7O_7Cl_4Na$,		4.39

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2759	21.00	26.99
0.2936	22.36	27.01
Calculated for $C_{20}H_7O_7Cl_4Na$,		27.07

Hence this compound is the monosodium salt of tetrachlorgallein.

Tetrachlorgallein dissolves in an excess of sodium hydroxide with a deep blue color, probably forming a *tetra*sodium salt. This salt could not be isolated, however, because it is very rapidly oxidized by the air.

There are two facts which indicate that tetrachlorgallein can form at least two salts with sodium carbonate solution: (1) When an excess of tetrachlorgallein is used the solution has a claret-red color and contains a *mono*sodium salt as shown above, but with an excess of sodium carbonate the solution is purple and probably contains a di- or trisodium salt of tetrachlorgallein. (2) The monosodium salt of tetrachlorgallein is much more soluble in sodium carbonate solu-

tion than in water. Accordingly a number of attempts were made to prepare a di- or trisodium salt in various ways but in every case the product obtained was so rapidly oxidized in the air that analysis was useless.

Monopotassium Salt of Tetrachlorgallein.

This compound was prepared in aqueous solution from 30 grams of tetrachlorgallein and 2.7 grams of anhydrous potassium carbonate by the same method used in making the monosodium salt.[1] It resembles the sodium salt very closely in its appearance and properties. The air-dried material gave the following results on analysis:

Substance. Gram.	Silver chloride. Gram.	Chlorine. Per cent.
0.2961	0.2763	23.08
0.3946	0.3664	22.97
0.3495	0.3260	23.07
Calculated for $C_{20}H_7O_7Cl_4K.4H_2O$,		23.17

Substance. Gram.	Potassium sulphate. Gram.	Potassium. Per cent.
0.3761	0.0514	6.13
0.3296	0.0454	6.18
0.3727	0.0510	6.14
Calculated for $C_{20}H_7O_7Cl_4K.4H_2O$,		6.39

Hence this compound is the monopotassium salt of tetrachlorgallein and, like the sodium salt, contains four molecules of water of crystallization. The determination of this water of crystallization showed that the potassium salt, like the sodium salt, retains a half molecule of water when dried over phosphorus pentoxide to constant weight *in vacuo* (I) or in carbon dioxide at 80° (II):

	Substance. Gram.	Loss. Gram.	Water. Per cent.
I	0.5766	0.0592	10.27
II	0.4020	0.0412	10.25
Calculated for $3\frac{1}{2}H_2O$ in $C_{20}H_7O_7Cl_4K.4H_2O$,			10.30

All the water is driven off by drying to constant weight

[1] Page 213.

in hydrogen at 157° (cumene), as shown by the following analyses made on the air-dried material:

Substance. Gram.	Loss. Gram.	Water. Per cent.
0.3525	0.0414	11.74
0.4711	0.0552	11.72
Calculated for $4H_2O$ in $C_{20}H_7O_7Cl_4K.4H_2O$,		11.77

Extraction with acetone showed that the potassium salt prepared as described above contained a trace of tetrachlorgallein, although the solution from which it was crystallized was perfectly clear. An attempt was therefore made to purify this salt by recrystallization from water. The recrystallized product was dried to constant weight at room temperature and analyzed:

Substance. Gram.	Silver chloride. Gram.	Chlorine. Per cent.
0.2491	0.2427	24.10
0.2739	0.2660	24.02
	Mean,	24.06

Substance. Gram.	Potassium sulphate. Gram.	Potassium. Per cent.
0.2694	0.0305	5.08
0.3089	0.0351	5.10
0.2650	0.0308	5.22
0.3110	0.0358	5.17
	Mean,	5.14

The ratio of chlorine to potassium in this salt shows clearly that potassium was removed by crystallization from water:

	Per cent.	Atomic weight.	Ratios.
Cl	24.06	÷ 35.46 =	0.6785 — 4.000
K	5.14	÷ 39.10 =	0.1315 — 0.775

Chlorine : potassium :: 4.000 : 0.775.

This loss of potassium is doubtless due to the hydrolysis of the monopotassium salt with the formation of tetrachlorgallein, the ratio found corresponding to that in a mixture of one molecule of tetrachlorgallein and three molecules of its monopotassium salt. It is evident that the salts of tetra-

chlorgallein can not be purified by crystallization from water but must be made from pure materials.

The monopotassium salt of tetrachlorgallein was also prepared by adding a solution of 7 grams of pure crystallized potassium acetate in 200 cc. of 94 per cent. ethyl alcohol to a boiling solution of 35 grams of pure anhydrous tetrachlorgallein in 1000 cc. of alcohol. The precipitate which formed was filtered off, washed thoroughly with hot alcohol, and dried to constant weight at room temperature. Analyses:

Substance. Gram.	Potassium sulphate. Gram.	Potassium. Per cent.
0.3965	0.0609	6.89
0.3957	0.0606	6.87

Calculated for $C_{20}H_7O_7Cl_4K.2H_2O$, 6.79

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.5083	34.86	24.32
0.4833	33.28	24.42

Calculated for $C_{20}H_7O_7Cl_4K.2H_2O$, 24.62

The properties of this compound were identical with those of the potassium salt made in aqueous solution. Loss of weight on heating was determined in the drying apparatus already described and an examination of the outflowing gases showed that the compound contained no alcohol. On drying to constant weight in carbon dioxide at 110° (toluene), the following results were obtained:

Substance. Gram.	Loss. Gram.	Water. Per cent.
0.2391	0.0116	4.85
0.2549	0.0124	4.86

Calculated for $1\frac{1}{2}H_2O$ in $C_{20}H_7O_7Cl_4K.2H_2O$, 4.69

Hence this salt resembles those already described in that it holds a half molecule of water quite firmly. All the water is lost at 157° (cumene), as shown by the following analyses:

Substance. Gram.	Loss. Gram.	Water. Per cent.
0.2391	0.0151	6.32
0.2549	0.0158	6.20

Calculated for $2H_2O$ in $C_{20}H_7O_7Cl_4K.2H_2O$, 6.25

The analytical data already given show very clearly that the potassium salt holds a half molecule of water very firmly, as is also true of the monosodium salt. This conduct is especially interesting in view of the fact that tetrachlorphthalic acid[1] crystallizes from water under all conditions with a half molecule of water.

Tetrachlorgallein Hydrate.

The tetrachlorgallein crystallized from methyl alcohol contains both methyl alcohol and water in varying proportions, depending on the conditions of crystallization. The crude tetrachlorgallein[2] is evidently a hydrate but is impure.

The preparation of a pure monohydrate of tetrachlorgallein was accomplished in the following manner: Some of the pure monosodium salt was dissolved in boiling distilled water in a flask, and very dilute hydrochloric acid was added drop by drop, the solution being kept boiling vigorously to prevent oxidation by the air. The reddish violet precipitate was filtered off, washed with hot water till free from chloride, and dried to constant weight at room temperature. This product lost one molecule of water when dried to constant weight at 158° (cumene) in a current of carbon dioxide:

Substance. Gram.	Loss. Gram.	Water. Per cent.
0.4313	0.0156	3.62
0.3417	0.0123	3.60
Calculated for $C_{20}H_8O_7Cl_4.H_2O$,		3.47

Chlorine determinations showed that the material dried at 158° was pure anhydrous tetrachlorgallein.

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2517	19.99	28.16
0.2931	23.28	28.16
Calculated for $C_{20}H_8O_7Cl_4$,		28.26

[1] Delbridge: THIS JOURNAL, **41**, 393.

[2] Page 209.

These results show that tetrachlorgallein hydrate contains one molecule of water and not two, as found by Graebe. They are also in accord with the results of Heller and Langkopf[1] on gallein hydrate, $C_{20}H_{12}O_7.H_2O$.

Tetrachlorgallein hydrate is a reddish violet, crystalline meal, consisting, as seen under the microscope, of minute rhomboidal plates. Its solubilities and conduct toward reagents are like those of the anhydrous compound. The hydrate, however, has a marked color, while the anhydrous tetrachlorgallein is nearly colorless. The hydrate is also formed in small amount when the pure monosodium or potassium salt is dissolved in water. Partial hydrolysis takes place, as has been stated before,[2] and the precipitated tetrachlorgallein hydrate can be filtered off. A further investigation of this hydrate is now in progress.

Lead Salt of Tetrachlorgallein.

When a solution of lead acetate is added to an aqueous solution of tetrachlorgallein monosodium salt, a blue precipitate is formed but the amount is small and some oxidation always takes place. The lead salt was therefore prepared as follows: A hot filtered solution of ten grams of pure tetrachlorgallein in 700 cc. of alcohol (94 per cent.) was slowly added to a boiling solution of 30 grams of pure crystallized lead acetate in 1000 cc. of alcohol. A dark blue precipitate formed at once, and after the mixture had been boiled for a half hour this precipitate was filtered off, transferred to a clean flask, and boiled with about 500 cc. of alcohol. The undissolved material was filtered off, washed with hot alcohol until the filtrate gave no color with hydrogen sulphide, and dried to constant weight at room temperature. The lead salt obtained in this way was a heavy, dark blue, crystalline powder. It is insoluble in alcohol and in water but water removes some lead from the compound, probably by hydrolysis. Dilute mineral acids decompose the salt with the formation of the red tetrachlorgallein hydrate, like that obtained from the

[1] Z. Farb. Ind., **5**, 115.
[2] Pages 215 and 218.

alkali salts. Caustic alkali solutions dissolve the lead salt with a bluish color, but it is practically insoluble in sodium carbonate solution.

The first product (I) made by the method described above was found to yield acetic acid when heated with phosphoric acid. A second product (II) was therefore prepared by the same method, except that the salt was washed with a large amount of hot alcohol in order to make sure that all lead acetate was removed from the material. The total volume of wash alcohol was about nine liters and the last seven liters were practically free from lead. Hence this salt could not have contained any lead acetate, but it still gave acetic acid on distillation with phosphoric acid. Both products were dried to constant weight at 100° and lost about 2.3 per cent. The same loss was found on drying the salt to constant weight *in vacuo* over phosphorus pentoxide.

Analyses of the two products dried at 100° gave the following results, those marked (II) having been obtained with the salt which had been very thoroughly washed with hot alcohol:

	Substance. Gram.	Silver chloride. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
I	0.4222	0.1881	.....	11.02
	0.5610	0.2522	.....	11.12
II	0.6271	.....	20.38	11.52
	0.6346	.....	20.68	11.56
Calculated for $C_{20}H_4O_9Cl_4Pb_3(C_2H_3O)_2$,				11.46

	Substance. Gram.	Lead sulphate. Gram.	Lead. Per cent.
I	0.6004	0.4369	49.71
	0.5561	0.4062	49.90
II	0.3983	0.2925	50.17
	0.5383	0.3965	50.32
	0.3117	0.2293	50.25
Calculated for $C_{20}H_4O_9Cl_4Pb_3(C_2H_3O)_2$,			50.22

The amount of acetyl was determined by decomposing the salt with syrupy phosphoric acid, distilling with steam, and

titrating the acetic acid in the distillate, phenoalphthlein being used as indicator:

	Substance. Gram.	Tenth-normal sodium hydroxide. cc.	C_2H_3O. Per cent.
I	0.6258	9.63	6.62
	0.5834	8.57	6.32
II	1.3696	14.54	4.57
	1.3514	14.60	4.65
Calculated for $C_{20}H_4O_9Cl_4Pb_3(C_2H_3O)_2$,			6.95

It seemed likely that the low results on acetyl in the second salt were due to loss of acetic acid by hydrolysis during the continued washing with hot alcohol. The correctness of this view was shown by extracting this second salt with large quantities of hot alcohol and then determining the amount of acetyl in the residue. On analysis, 1.3053 gram of substance required 8.20 cc. of tenth-normal sodium hydroxide solution, thus giving 2.7 per cent. of C_2H_3O, while the amount present before this extraction was 4.6 per cent. Hence this lead salt loses acetic acid on prolonged washing with hot alcohol and the fact that water removes lead from the salt is easily explained, since the acetic acid formed by hydrolysis partially decomposes the salt, yielding a soluble acetate of lead. It is evident, however, from the analytical data that the lead salt of tetrachlorgallein prepared as described has the composition represented by the formula

$$C_{20}H_4O_9Cl_4Pb_3(C_2H_3O)_2.$$

The lead salt of gallein, $C_{20}H_8O_7(PbOH)_4$, obtained by Orndorff and Brewer[1] was made in *aqueous* solution and was very thoroughly washed with water. This process, as we have shown, removes acetic acid from the lead salt, which may account for the difference in composition of the two salts. Furthermore, the lead salt of gallein was not analyzed for acetyl groups which may have been present. Tetrachlorgallein is moreover a stronger acid than gallein, which may account for the fact that its lead salt contains only three atoms of lead while the lead salt of gallein contains four. It seems

[1] This Journal, **26**, 134.

quite likely that if the lead salt of gallein were prepared in *alcoholic* solution it would have a composition similar to that of the lead salt of tetrachlorgallein.

Barium Salt of Tetrachlorgallein.

When tetrachlorgallein and barium carbonate are boiled with water a red solution is formed, but the slight solubility of the barium salt of tetrachlorgallein and the ease with which it is oxidized render this method unsuitable for the preparation of the compound. The barium salt was finally prepared in aqueous solution in the following manner: One liter of water was heated to boiling in a two-liter flask connected with a return condenser, 5.2 grams of pure tetrachlorgallein were added, and then enough normal ammonium hydroxide solution to form a tetrammonium salt (0.68 gram of anhydrous ammonia). The resulting bluish purple solution was filtered as rapidly as possible and kept boiling vigorously while a solution of 6 grams of pure crystallized barium chloride in 300 cc. of water was added rather slowly. A dark brown precipitate separated immediately, and after the mixture had been boiled for about fifteen minutes this precipitate was filtered off, washed with water until free from chloride, and dried to constant weight at room temperature. This air-dried barium salt lost about 11.5 per cent. of water when dried to constant weight at 100°, while the loss of weight *in vacuo* over phosphorus pentoxide was 11.3 per cent.

Analyses of the salt dried at 100° gave the following results:

Substance. Gram.	Barium sulphate. Gram.	Barium. Per cent.
0.3311	0.1091	19.39
0.4551	0.1505	19.46
Calculated for $C_{20}H_6O_7Cl_4Ba.3H_2O$,		19.87

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2164	13.20	21.63
Calculated for $C_{20}H_6O_7Cl_4Ba.3H_2O$,		20.52

The high chlorine content of this product is probably due to the presence of some tetrachlorgallein formed from the

barium salt by hydrolysis[1] in washing out the excess of barium chloride. Notwithstanding the poor agreement between the calculated percentages and those found on analysis, still the ratio of chlorine to barium is approximately 4: 1.

	Per cent.		Atomic weight.		Ratios.
Cl	21.63	÷	35.46	=	0.610 — 4.00
Ba	19.42	÷	137.37	=	0.141 — 0.93

This ratio is the more interesting because in the preparation of the salt the materials used were in such a proportion that chlorine : barium : : 4 : 2.14.

An attempt was next made to prepare a pure barium salt by adding a clear solution of barium hydroxide (one molecule) in 85 per cent. alcohol to a filtered alcoholic solution of pure tetrachlorgallein hydrate (two molecules). The barium salt obtained in this way was washed with hot alcohol, in which it is insoluble, and dried to constant weight at 100°. It was a greenish blue in color and seemed to be amorphous. It was slightly soluble in hot water, forming a red solution from which dilute acids precipitated the red tetrachlorgallein hydrate. Analyses:

Substance. Gram.	Barium sulphate. Gram.	Barium. Per cent.
0.4451	0.1453	19.21
0.3928	0.1280	19.18
Calculated for $C_{20}H_6O_7Cl_4Ba.3H_2O$,		19.87

Substance. Gram.	Tenth-normal silver nitrate cc.	Chlorine. Per cent.
0.3498	20.66	20.94
0.3499	20.62	20.90
Calculated for $C_{20}H_6O_7Cl_4Ba.3H_2O$,		20.52

This barium salt, like the one made in aqueous solution, seemed, according to the analyses, to contain some tetrachlorgallein. The ratio of chlorine to barium in the materials used in preparing the compound was 8: 1 but the actual ratio

[1] It is to be noted that the monosodium and potassium salts are also hydrolyzed in this manner.

found in the salt was 4:0.95, practically the same as that in the barium salt made in aqueous solution.

The water of crystallization in the barium salt dried at 100° could not be determined with accuracy because its complete removal requires so high a temperature that the salt itself is decomposed. While it has been impossible to prepare a perfectly pure barium salt of tetrachlorgallein, nevertheless the analyses of the two products described above show clearly that the barium salt of tetrachlorgallein has the composition represented by the formula $C_{20}H_6O_7Cl_4Ba.xH_2O$.

The barium salt of oxyhydroquinonetetrachlorphthalein made by Osorovitz[1] also has the composition represented by the formula $C_{20}H_6O_7Cl_4Ba$.

Tetrachlorgallein Tetracetate.

Anhydrous tetrachlorgallein (10 grams), fused sodium acetate (10 grams) and acetic anhydride (40 grams) were boiled together for one hour in a flask connected with a return condenser, the mixture allowed to cool, and then poured slowly into ice water. The light colored oil which separated at first solidified after a short time to a pearl-gray, crystalline cake. This crude acetate was ground with water, filtered off, washed thoroughly with water, and allowed to dry. Benzene proved to be an ideal solvent for crystallizing the compound. The benzene solution was boiled a number of times with small portions of boneblack, filtered carefully, concentrated to a small volume, and then cooled rapidly with constant stirring in order to obtain small crystals which were found to be purer than large crystals formed on gradual cooling. This product was filtered off with suction, washed with a little very cold benzene, and again crystallized from benzene, using the same precautions as before. The acetate thus obtained was perfectly colorless and melted sharply at 255° (uncor.). This melting point was not changed by repeated crystallization from alcohol and from benzene. The compound was dried to constant weight in carbon dioxide

[1] Ber. d. chem. Ges., **36**, 1076 (1903).

at 110° and analyzed for chlorine with the following results:

	Substance. Gram.	Silver chloride. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
1	0.3247	0.2784	.....	21.21
2	0.3295	0.2816	.....	21.14
3	0.3749	.....	22.31	21.10
4	0.3806	.....	22.68	21.13
	Calculated for $C_{20}H_5O_7Cl_4(C_2H_3O)_3$,			22.59
	Calculated for $C_{20}H_4O_7Cl_4(C_2H_3O)_4$,			21.18
	Calculated for $C_{20}H_3O_7Cl_4(C_2H_3O)_5$,			19.93

Analyses 1 and 2 were made on a product crystallized from benzene alone while that used in 3 and 4 had been crystallized from benzene, alcohol, benzene, alcohol and benzene, successively. These analyses indicate very clearly that the compound is tetrachlorgallein tetracetate, and this was further proven by determining the number of acetyl groups in the compound analyzed in 3 and 4 above. For this purpose the following modification of the Wenzel[1] method was used: The powdered acetate was placed in a 500 cc. balloon flask closed by a two-hole rubber stopper carrying a separatory funnel whose stem extended to the bottom of the flask and a 30 cm. Vigreux distillation tube connected with a spiral condenser whose lower end dipped into a measured amount of tenth-normal sodium hydroxide solution properly protected from the air. Five cc. of sulphuric acid, 2:1, were added through the funnel and the flask heated in boiling water for thirty minutes, after which five cc. of water were introduced and the heating continued for one hour longer. Twenty-five cc. of the sodium phosphate solution, prepared according to Wenzel's directions, were then added and the acetic acid distilled off with steam passed into the flask through the separatory funnel. This steam was generated from a dilute solution of barium hydroxide and was therefore free from carbon dioxide. Preliminary experiments showed that the Vigreux tube completely removes all entrained liquid, even when the distillation is exceedingly rapid. The volume of the

[1] Monatsh. Chem., **18**, 659; compare Orndorff and Brewer: This Journal, **26**, 121.

distillate was about 400 cc. The excess of sodium hydroxide in this distillate was titrated with tenth-normal hydrochloric acid solution, phenolphthalein being used as indicator. The solution was then acidified with hydrochloric acid, a little starch solution added, and the sulphurous acid determined by titration with tenth-normal iodine solution. Under these conditions the presence of the small amount of phenolphthalein has no effect on the results. The following analyses were made by this method on the acetate dried to constant weight at 110°.

Substance. Gram.	Tenth-normal iodine. cc.	Net tenth-normal sodium hydroxide. cc.	C_2H_3O. Per cent.
0.3675	0.25	21.90	25.64
0.3786	0.00	22.55	25.62
Calculated for $C_{20}H_4O_7Cl_4(C_2H_3O)_4$,			25.69

Tetrachlorgallein tetracetate is very soluble in acetone, acetic acid and hot benzene, much less soluble in alcohol, ether, chloroform and cold benzene, while in ligroin it is practically insoluble. When the hot benzene solution is allowed to cool slowly, large transparent crystals are formed which lose benzene in the air, becoming opaque and eventually crumbling to a white powder. Heated in a capillary melting point tube, the acetate dried at 110° undergoes a marked contraction at 155°–160° but melts sharply at 255° (uncor.). The corrected melting point, taken with an Anschütz thermometer (250°–300°), was found to be 261°.

Cold five per cent. sodium carbonate solution has at first no apparent action on tetrachlorgallein tetracetate, but on standing the solution gradually acquires a pink color and at the same time shows a green fluorescence. This pink color and green fluorescence become very marked on the addition of a little alcohol. On longer standing the solution becomes purple and the fluorescence disappears entirely. These color changes are evidently due to gradual saponification of the acetate, and the compound dissolving with a pink color and green fluorescence is probably a sodium salt of a tetrachlorgallein diacetate analogous in structure[1] to fluorescein.

[1] Compare the conduct of the tetrachlorgallein methyl ester acetate, page 241.

Solutions of sodium hydroxide saponify the tetrachlorgallein tetracetate slowly in the cold, rapidly on warming, forming a deep blue solution which is rapidly oxidized in the air. Dry hydrochloric acid gas has no apparent effect on the solid tetrachlorgallein tetracetate. Concentrated sulphuric acid dissolves the compound even in the cold, forming a deep red solution, and if this solution is diluted with water, a dull lavender precipitate is formed which gives all the color reactions of tetrachlorgallein. Unlike the forms of tetrachlorgallein already described, this lavender precipitate is soluble in ether and the ethereal solution, on evaporation, gives crystals which are white at first but slowly turn pink in the air. Colorless crystals showing this same peculiar conduct were also obtained by crystallizing the lavender precipitate from acetone. Further investigation of this lavender precipitate is necessary in order to determine whether it is really a new form of tetrachlorgallein or a partially acetylated compound.

Tetrachlorgallin Tetracetate.

An attempt was made to prepare tetrachlorgall*in* by a method similar to that used by Buchka[1] in the preparation of his so-called hydrogallein, shown by Orndorff and Brewer[2] to be identical with gallin. Tetrachlorgallein was dissolved in a small excess of potassium hydroxide solution in an atmosphere of hydrogen, and zinc dust added cautiously to the cold solution. The mixture was allowed to stand for one hour but no change could be observed and so it was heated for one hour at 50°. The blue color gradually disappeared and the brown solution was cooled, made acid with sulphuric acid, and extracted with ether. The aqueous solution, however, contained chloride in large amount, showing that chlorine had been removed from the tetrachlorgallein during the reduction. The experiment was therefore repeated, the mixture being kept in an atmosphere of hydrogen at room temperature all the time. There was no apparent change during the first two days, but after that time the color changed grad-

[1] Ann. Chem. (Liebig), **209**, 251.
[2] This Journal, **26**, 125.

ually from blue to brown, two weeks being required for the complete disappearance of the blue color. Although the temperature had never exceeded 25°, chlorine was split off in this experiment, as in the preceding one, and this method was therefore abandoned.

An attempt was next made to prepare tetrachlorgallin acetate by the method used by Orndorff and Brewer[1] in the preparation of gallin tetracetate. A mixture of 10 grams of tetrachlorgallein, 10 grams of sodium acetate, 5 grams of zinc dust and 80 grams of acetic anhydride was boiled on a sand bath for three hours, cooled, and poured into ice water. A brown oil separated but the aqueous solution contained chloride in large amount, showing that chlorine is removed from tetrachlorgallein by this method as well as by the action of zinc and potassium hydroxide.

After a number of unsuccessful attempts the tetrachlorgallin acetate was finally prepared by a method which proved to be very satisfactory both in simplicity and in the yield obtained. Ten grams of pure tetrachlorgallein tetracetate were dissolved in 200 cc. of glacial acetic acid in a flask connected with a return condenser, 3 grams of zinc dust and a few drops of copper sulphate solution added, and the mixture boiled on a sand bath until all the tetrachlorgallein tetracetate had been reduced. The method of determining this point was as follows: A small test portion removed with a pipette was diluted with water and the resulting white precipitate filtered off with suction and dissolved in concentrated sulphuric acid by gentle warming. This sulphuric acid solution was then poured into water. If a reddish turbidity was observed, the tetrachlorgallein tetracetate was not all reduced and hence the boiling was continued. Eventually the sulphuric acid solution prepared as described gave absolutely no turbidity when poured into water, indicating that reduction was complete. The time required for this reduction was usually about three hours and the solution contained no chloride, although boiling was continued in one case for ten hours. When the above test showed that reduction was

[1] This Journal, **26**, 129.

complete, the acetic acid solution was filtered from the undissolved zinc and zinc acetate, concentrated to half its original volume, and poured into ice water. The white flocculent precipitate which separated was filtered off, washed with cold water, and dried on a porous plate.

This crude product was purified by repeated crystallization from 94 per cent. alcohol until the melting point became constant. The compound thus obtained was pure white and melted sharply at 221°–222° (uncor.). A portion of this product was recrystallized from 80 per cent. acetone and from benzene, successively, but the melting point remained constant, indicating that the compound was perfectly pure. The product crystallized from alcohol was dried to constant weight in the air at room temperature but still contained alcohol of crystallization which was determined by drying to constant weight at 110° in a current of carbon dioxide. The volatilized alcohol was condensed and identified by its odor and by conversion into iodoform.

Substance. Gram.	Loss. Gram.	Alcohol. Per cent.
0.1816	0.0172	9.47

Calculated for $C_{20}H_6O_7Cl_4(C_2H_3O)_4.1\frac{1}{2}C_2H_5OH$, 9.32

The compound dried to constant weight at 110° was analyzed for chlorine:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2300	13.74	21.18

Calculated for $C_{20}H_6O_7Cl_4(C_2H_3O)_4$, 21.10

Tetrachlorgallin tetracetate resembles gallin tetracetate in its properties and conduct toward reagents. It dissolves in cold concentrated sulphuric acid with a red color, and when this solution is diluted with water it becomes colorless at first and then turns green on standing in the air. The sulphuric acid probably saponifies the acetate and then condenses the tetrachlorgallin to tetrachlorcoerulin, giving a colorless solution in water which is oxidized in the air to the green tetrachlorcoerulein. The tetrachlorgallin tetracetate

dissolves in dilute sodium carbonate solution, liberating carbon dioxide and thus conducting itself like an acid. The resulting solution is colorless if protected from the air but turns pink very quickly in the air and shows at the same time a marked greenish fluorescence. This pink color and green fluorescence is doubtless due to simultaneous saponification and oxidation, resulting in the production of the same compounds as those formed from tetrachlorgallein tetracetate[1] under these conditions. The tetrachlorgallin tetracetate itself is rather easily oxidized to tetrachlorgallein tetracetate, as was discovered in an attempt to purify some of the compound which had a faint yellow color although it melted at the proper temperature, 221°. This material was dissolved in 94 per cent. alcohol, the solution boiled with bone-black for fifteen minutes, filtered, and evaporated to crystallization. The crystals thus obtained were white but proved to be pure tetrachlorgallein tetracetate, as shown by the melting point, 255°, by their conduct toward sodium carbonate solution, and by the reddish precipitate formed on adding water to a solution of the crystals in concentrated sulphuric acid. The yield of tetrachlorgallein tetracetate in this case was practically quantitative.

The percentage composition of tetrachlorgallin tetracetate, $C_{20}H_6O_7Cl_4(C_2H_3O)_4$, is practically the same as that of tetrachlorgallein tetracetate, $C_{20}H_4O_7Cl_4(C_2H_3O)_4$, and hence it is impossible to distinguish between these two compounds by analysis. Accordingly the composition and structure of tetrachlorgallin tetracetate were further established by the preparation and analysis of its silver salt.

Silver Salt of Tetrachlorgallin Tetracetate.

That tetrachlorgallin tetracetate is an acid is shown by the fact that it dissolves in sodium carbonate solution with evolution of carbon dioxide. The sodium salt thus formed is too easily decomposed to permit of its isolation. A large number of attempts to prepare a silver salt of tetrachlorgallin tetracetate gave negative results, but this compound

[1] Page 228.

was finally obtained by the following simple method: Commercial acetone was dried with calcium chloride, carefully fractionated through a 40 cm. Vigreux distillation tube, and the main portion, distilling within one-fifth of a degree, boiled for one hour with solid silver nitrate in a flask connected with a return condenser. The acetone was then distilled off and used as the solvent in the preparation of the silver salt of tetrachlorgallin tetracetate. A solution of 5 grams of dried tetrachlorgallin tetracetate in 100 cc. of this acetone was added rapidly to a solution of 25 grams of silver nitrate in a mixture of 25 cc. of water and 125 cc. of the purified acetone. The resulting solution was perfectly clear at first, but within a few minutes fine white crystals began to separate. After the mixture had been allowed to stand for several hours in the dark, these white crystals were filtered off, washed with the purified acetone, and dried in the air. Analysis showed that this material was not pure and it was therefore crystallized from dry benzene previously digested with silver nitrate and carefully distilled. The perfectly white product thus obtained was dried to constant weight at room temperature and analyzed. Dried to constant weight at 110° in carbon dioxide, the air-dried substance lost one molecule of benzene:

Substance. Gram.	Loss. Gram.	Benzene. Per cent.
0.2432	0.0219	9.01
0.3813	0.0347	9.10
Calculated for $C_{20}H_5O_7Cl_4(C_2H_3O)_4Ag.C_6H_6$,		9.11

The compound dried to constant weight at 110° was analyzed for silver and chlorine. The silver could not be determined by burning out the organic matter because some silver chloride was always formed. The determination of silver was therefore conducted in the following manner: A weighed amount of the silver salt was dissolved in 94 per cent. alcohol previously purified by digestion with silver nitrate and subsequent distillation. Nitric acid was then added and the silver determined at once by titration with tenth-normal

ammonium sulphocyanate solution, ammonium ferric sulphate being used as the indicator. The results obtained by this method were as follows:

Substance. Gram.	Tenth-normal ammonium sulphocyanate. cc.	Silver. Per cent.
0.2213	2.84	13.84
0.3466	4.45	13.85
Calculated for $C_{20}H_5O_7Cl_4(C_2H_3O)_4Ag$,		13.85

Chlorine in the salt dried at 110° was determined by the modification of the lime method already described.[1] Since the compound also contained silver, this method gave only the chlorine in excess of that which combined with the silver to form silver chloride. Hence the total chlorine was computed by adding to the percentage of chlorine found on titration the percentage of chlorine equivalent to the determined silver content of the compound.

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine not combined with silver. Per cent.	Chlorine to form silver chloride. Per cent.	Total chlorine. Per cent.
0.2576	9.90	13.63	4.55	18.18
0.3183	12.23	13.62	4.55	18.17
Calculated for $C_{20}H_5O_7Cl_4(C_2H_3O)_4Ag$,		13.66	4.55	18.21

The analyses given above show very clearly that this compound is the silver salt of tetrachlorgallin tetracetate and thus furnish a direct proof of the structure of tetrachlorgallin tetracetate itself.

The silver salt of tetrachlorgallin tetracetate, when crystallized from benzene, is perfectly white and has no definite melting point but decomposes at 230°–240°. It is quite stable toward light, remaining white for many weeks in diffused daylight. It dissolves in alcohol and acetic acid as well as in benzene, but is insoluble in water and in hot dilute nitric acid. Concentrated nitric acid decomposes the compound readily. With solutions of sodium carbonate and sodium hydroxide, reduction takes place with the formation of metallic silver.

[1] Delbridge: This Journal, **41**, 397.

Tetrachlorgallein Tetraphenylcarbamate.

Anhydrous tetrachlorgallein was heated with an excess of phenyl isocyanate for fifteen minutes but the formation of the carbamate was attended by so much charring that the following method was adopted: A mixture consisting of 10 grams of anhydrous tetrachlorgallein, 15 grams of phenyl isocyanate and 300 cc. of anhydrous cumene was boiled vigorously on a sand bath for three hours. The tetrachlorgallein gradually dissolved, forming a brown solution. This was filtered while hot and allowed to cool, being protected from the moisture of the air by a calcium chloride tube. After several hours the tetrachlorgallein phenylcarbamate separated in brownish yellow crystals which were filtered off and washed with a little cold benzene to remove the excess of cumene and phenyl isocyanate. This crude product was allowed to dry and then dissolved in dry ether. The ether solution was concentrated and allowed to stand. A crop of crystals was thus obtained which proved to be mostly diphenylurea (m. p. 235°), notwithstanding the effort to exclude moisture in the preparation of the compound. Further concentration of the ether solution gave a product containing only traces of diphenylurea. This product was crystallized twice more from anhydrous ether and then contained no diphenylurea, as shown by the fact that it dissolved completely in sodium hydroxide solution. This material was dried to constant weight *in vacuo* over sulphuric acid and analyzed. A small portion was heated for one hour at 80° but lost no weight and hence contained no ether of crystallization.

An attempt was made to determine the chlorine in this phenylcarbamate by the lime method, but the silver chloride precipitate was found to contain some silver cyanide. The determination of chlorine was therefore carried out by the Carius method with the following results:

Substance. Gram.	Silver chloride. Gram.	Chlorine. Per cent.
0.2384	0.1371	14.22
0.1474	0.0861	14.44
Calculated for $C_{20}H_4O_7Cl_4(C_6H_5NHCO)_4$,		14.50
Calculated for $C_{20}H_5O_7Cl_4(C_6H_5NHCO)_3$,		16.51
Calculated for $C_{20}H_3O_7Cl_4(C_6H_5NHCO)_5$,		12.92

This compound is therefore tetrachlorgallein *tetra*phenylcarbamate. Attempts were made to determine nitrogen in this substance by both the Dafert and Gunning modifications of the Kjeldahl method, but neither of these methods are suitable, as the results obtained varied over a wide range, the average being somewhat lower than the calculated value for a tetraphenylcarbamate.

Tetrachlorgallein tetraphenylcarbamate prepared as described is a colorless, well crystallized compound which melts with decomposition at 182° (uncor.). It becomes highly electrified when rubbed and the particles lose this electric charge very slowly. The compound resembles tetrachlorgallein tetracetate in its conduct toward concentrated sulphuric acid, dissolving even in the cold with a deep red color. When this sulphuric acid solution is diluted with water a lavender precipitate is formed like that obtained from tetrachlorgallein tetracetate. Tetrachlorgallein tetraphenylcarbamate dissolves in dilute solutions of sodium carbonate with a pink color and green fluorescence. When heated or on standing, this solution becomes purple, owing to saponification, and loses its fluorescence. Dilute ammonia acts much like sodium carbonate solution, but sodium hydroxide solutions saponify the carbamate very rapidly, giving the deep blue solution characteristic of tetrachlorgallein. Alcohol dissolves the carbamate with a pink color and green fluorescence, but the addition of the slightest trace of acid destroys this color and fluorescence, so that they may be due to the presence of a trace of alkali in the alcohol used.

Tetrachlorgallein Methyl Ester.

Tetrachlorgallein is a fairly strong acid, since it decomposes carbonates and acetates, and so it seemed likely that an ester might be formed on boiling with methyl alcohol and hydrochloric acid. Accordingly 20 grams of pure anhydrous tetrachlorgallein and 200 grams of a three per cent. solution of hydrochloric acid gas in absolute methyl alcohol were boiled together for four hours in a flask connected with a return condenser. The deep red solution was then filtered, cooled and

poured into about six liters of cold water. A reddish black precipitate separated at once and this was filtered off on a muslin filter, washed with cold water till free from hydrochloric acid, pressed out on a porous plate, and dried *in vacuo* over phosphorus pentoxide. This product differed from tetrachlorgallein in that it was soluble in ether, in chloroform and in benzene, none of which dissolves tetrachlorgallein. The ethereal solution, on evaporation, gave small, dark red crystals which were filtered off, washed with ether, and allowed to dry. They were green in reflected light but dark red by transmitted light, and contained ether of crystallization which was partially lost on standing. The compound was dried to constant weight in carbon dioxide at 110° and analyzed for chlorine. The amount found corresponded very closely with that calculated for a *dimethyl* ester, but methoxyl determinations by the Zeisel method showed clearly that the compound contained only *one* methoxyl group. The material dried to constant weight at 110° was therefore heated to 157° and lost *ether* at this temperature. It could not be brought to constant weight, however, owing to decomposition and hence crystallization of the substance from ether was abandoned.

Benzene proved to be an excellent solvent for purifying the ester, and the dry crude product was boiled with benzene, the deep red solution filtered while hot, and allowed to stand in a cool place. After twenty-four hours the ester had separated in very dark red, microscopic crystals which were filtered off, washed with benzene, and dried at room temperature. This product contained benzene of crystallization which was completely driven off by drying to constant weight in carbon dioxide at 157°. This dried substance gave results on analysis which show clearly that it was the *mono*methyl ester of tetrachlorgallein:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2490	19.33	27.53
0.2530	19.66	27.55
Calculated for $C_{20}H_7O_7Cl_4(CH_3)$,		27.49

The methoxyl content was determined by the Zeisel method

with the apparatus of Decker.[1] For the complete saponification of the ester it was necessary to use 20 cc. of a mixture of equal volumes of acetic anhydride and hydriodic acid, sp. gr. 1.96.

Substance. Gram.	Silver iodide. Gram.	CH_3O. Per cent.
0.3873	0.1743	5.95
Calculated for $C_{20}H_7O_7Cl_4(CH_3)$,		6.01

Hence tetrachlorgallein forms a monomethyl ester when boiled with methyl alcohol and hydrochloric acid. The same ester was also obtained by boiling a mixture of 15 grams of tetrachlorgallein, 100 cc. of methyl alcohol, and 20 cc. of concentrated sulphuric acid for one hour. The formation of an ester by these two methods is especially interesting because, according to the Victor Meyer rule,[2] tetrachlorgallein ought not to form an ester in this way, since it contains substituents in both the positions ortho to the carboxyl group. Oxyhydroquinonetetrachlorphthalein,[3] phenoltetrachlorphthalein and tetrabromphenoltetrachlorphthalein[4] do not form esters in this way. With tetrachlorgallein, however, esterification takes place rapidly and almost quantitatively. The crude ester made from 5 grams of pure tetrachlorgallein by boiling for four hours with a three per cent. solution of hydrochloric acid in methyl alcohol was extracted with ether, in which tetrachlorgallein is insoluble, and the insoluble residue was found to weigh only 0.2 gram, showing that 96 per cent. of the tetrachlorgallein had been esterified by this treatment.

Tetrachlorgallein methyl ester, crystallized from benzene and dried to constant weight at 157°, is a dark red, crystalline powder with a slight greenish luster. Heated in a capillary melting point tube it imparts a red color to the glass at 240°–250° and melts with decomposition at 285°–290° (uncor.). It is extremely soluble in acetone, alcohol, ethyl acetate, acetic acid and chloroform, less soluble in benzene and ether, and practically insoluble in ligroin. Supersaturated solutions

[1] Ber. d. chem. Ges., **36**, 2895.
[2] *Ibid.*, **27**, 510, 1580 and 3146. See also J. Am. Chem. Soc., **30**, 1895.
[3] Osorovitz: Ber. d. chem. Ges., **36**, 1076.
[4] Orndorff and Black: This Journal, **41**, 366 and 382.

of the ester are easily formed by concentration and are rather stable, the separation of the ester often taking place only after long standing. This property is common to most of the derivatives of tetrachlorgallein described in this paper, especially to solutions of the sodium and potassium salts in water and of the tetracetate in benzene.

The conduct of the methyl ester toward alkaline solutions is almost the same as that of tetrachlorgallein itself. Both dissolve in sodium hydroxide solution with a deep blue color, in sodium carbonate and bicarbonate with a purple color, and in sodium acetate solution with a reddish purple color. Solutions of borax dissolve the ester with a bluish color, while tetrachlorgallein gives a reddish purple. Alcoholic solutions of both tetrachlorgallein and its methyl ester give a dark blue precipitate with lead acetate. The ester is not saponified by a dilute solution of sodium hydroxide although the blue color of the solution is just like that given by tetrachlorgallein itself. The truth of this assertion was established by the following experiments: About 0.1 gram of the pure methyl ester was dissolved in 50 cc. of cold tenth-normal sodium hydroxide and the deep blue solution immediately acidified with dilute hydrochloric acid. The red solution thus formed was extracted with ether, whereupon the ether became deep red while the aqueous layer became colorless and perfectly *clear*. Since tetrachlorgallein is insoluble both in ether and in water, this conduct can be explained only on the basis that the methyl ester dissolves in tenth-normal sodium hydroxide solution without saponification. The above experiment was repeated with some methyl ester to which a little tetrachlorgallein had been added, but the ether extraction left a turbid aqueous solution containing tetrachlorgallein in suspension. In one case a solution of the ester in tenth-normal sodium hydroxide was allowed to stand for one hour, and even then no saponification could be detected although some oxidation had taken place.

A marked difference between tetrachlorgallein and its methyl ester lies in the conduct of these two compounds toward a solution of hydrochloric acid (sp. gr. 1.10). Tetra-

chlorgallein is insoluble in this acid, while the methyl ester dissolves easily, especially in the hot acid, forming a red solution, and when the hot saturated solution is allowed to cool the methyl ester hydrochloride crystallizes out. In this respect the tertachlorgallein methyl ester resembles gallein to a marked degree as might be expected, since the introduction of the positive methyl group into the tetrachlorphthalic acid residue of tetrachlorgallein would tend to neutralize the effect of the negative chlorine atoms.

Feuerstein and Dutoit[1] prepared a triacetate of oxyhydroquinonephthalein ethyl ester and a monacetate of fluorescein ethyl ester by boiling these esters with acetic anhydride and sodium acetate. This method was tried with tetrachlorgallein methyl ester, a mixture of 5 grams of the ester, 5 grams of sodium acetate and 30 grams of acetic anhydride being boiled for thirty minutes. The crude product was precipitated with water, filtered off, and dried at room temperature. By crystallization from a mixture of acetone and petroleum ether a dark red product was obtained which melted at 215°–220° (uncor.) and which was practically insoluble in cold aqueous sodium carbonate, bicarbonate and caustic alkali, although the latter slowly dissolves the substance with a blue color and green fluorescence. It dissolved in alcohol with an orange-yellow color and a green fluorescence which became more marked on the addition of a little sodium carbonate or hydroxide solution. Analysis of the product dried to constant weight at 60° showed that it was a monacetate of the methyl ester. 0.2588 g. substance required 18.61 cc. of tenth-normal silver nitrate solution. Chlorine, calculated for the methyl ester monacetate, 25.43 per cent.; found, 25.50 per cent.

In a second attempt to prepare the methyl ester triacetate, 10 grams of the ester were boiled with 50 grams of acetic anhydride for fifteen minutes, when the color of the solution, which was deep red at first, became orange-yellow. About 25 cc. of methyl alcohol were then added and the solution allowed to stand overnight. The orange colored crystals which had separated were filtered off and recrystallized from benzene. The product thus obtained was practically colorless and melted at 254° (uncor.), showing a marked contrac-

[1] Ber. d. chem. Ges., **34**, 2639.

tion at 160°. These facts indicated that the compound was tetrachlorgallein tetracetate and a determination of chlorine in the substance dried to constant weight at 110° confirmed this view:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2757	16.37	21.05
Calculated for tetrachlorgallein tetracetate,		21.18

Tetrachlorgallein methyl ester dissolves in acetic anhydride in the cold with a deep red color which changes to orange after a few days. It seemed likely that this color change was due to the formation of an acetate of the ester, and so water was added to the acetic anhydride solution prepared in this way, and the oil which separated was allowed to solidify. The hard cake was removed and dried. All attempts to crystallize this product from various solvents resulted in failure and it was eventually dissolved in benzene and precipitated with petroleum ether. The material obtained in this manner was a reddish brown powder which melted at 190°–200° and dissolved in alcohol with a marked greenish fluorescence which was increased by the addition of a little alkali. A portion dried to constant weight at 157° was analyzed for chlorine with the following result:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2564	17.65	24.41
Calculated for a methyl ester monacetate,		25.43
Calculated for a methyl ester diacetate,		23.65
Calculated for a methyl ester triacetate,		22.10

It is evident from this analysis that the material was a mixture of acetates, and although it was impossible to acetylate the methyl ester completely, yet the fact that this mixture of acetates dissolved in alcohol with fluorescence is important, since neither tetrachlorgallein nor its methyl ester give fluorescent solutions. This conduct is especially interesting in view of the fact that tetrachlorgallein tetracetate gradually imparts a pink color and green fluorescence to solutions of

sodium carbonate or ammonia. The fluorescence in this case is doubtless due to the formation of the sodium salt of a tetrachlorgallein di- or triacetate analogous in structure to the di- or triacetate of the methyl ester and also to fluorescein.

Tetrachlorgallein Methyl Ester Hydrochloride.

Tetrachlorgallein methyl ester dissolves in benzene with a deep red color, and if dry hydrochloric acid gas is passed into this solution, the color becomes purple, and a dark red hydrochloride gradually crystallizes out. This hydrochloride has a green luster when dried and is more stable in the air than tetrachlorgallein hydrochloride. It is slightly soluble in benzene, ether, alcohol and acetone with a reddish purple color. It is only superficially decomposed by cold water and the complete removal of all the hydrochloric acid requires the use of boiling water. The amount of hydrochloric acid found on analysis was somewhat less than that calculated for a monohydrochloride and this was doubtless due to the presence of benzene of crystallization in the compound, but it was impossible to drive off the benzene by heat without some loss of hydrochloric acid.

In order to overcome this difficulty, the hydrochloride was prepared by exposing the pure, finely ground methyl ester to the action of dry hydrochloric acid gas until the weight became constant. Hydrochloric acid was taken up rapidly with evolution of heat, the amount of acid absorbed being greater than that calculated for a monohydrochloride. The product thus formed lost some hydrochloric acid readily, however, and it was therefore placed in a slow stream of dry air and weighed at intervals of five minutes until the weight became constant. The resulting compound was the anhydrous *mono*hydrochloride of tetrachlorgallein methyl ester, as shown by the following data:

Substance.	Gain in dry HCl.	Net gain after exposure to air.	Hydrochloric acid.
Gram.	Gram.	Gram.	Per cent.
0.2879	0.0340	0.0205	6.65
Calculated for $C_{20}H_7O_7Cl_4(CH_3).HCl$,			6.60

The properties and conduct of this compound were the same as those of the methyl ester hydrochloride made in benzene solution as described. When dissolved in ether, this hydrochloride is oxidized rapidly by the air, the solution becoming brownish yellow. The solid compound is more stable than tetrachlorgallein hydrochloride, as would be expected, since tetrachlorgallein is less basic than its methyl ester. In accord with this statement is the fact already mentioned that the methyl ester hydrochloride is formed by dissolving the methyl ester in aqueous hydrochloric acid (sp. gr. 1.10).

Tetrachlorgallein Ethyl Ester.

Twenty grams of pure anhydrous tetrachlorgallein were boiled for four hours with 200 grams of a three per cent. solution of hydrochloric acid in absolute ethyl alcohol, the crude ester precipitated with water, washed thoroughly, dried at room temperature, and purified by repeated crystallization from benzene. The product thus obtained contained benzene of crystallization and was therefore dried to constant weight in hydrogen at 157°. A chlorine determination in this dried material showed that it was the mono-ethyl ester of tetrachlorgallein.

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.3141	23.75	26.81
Calculated for $C_{20}H_7O_7Cl_4(C_2H_5)$,		26.76

Further proof that this compound was really the *mono*-ethyl ester was furnished by an ethoxyl determination made by Mr. E. H. Nichols:

Substance. Gram.	Silver iodide. Gram.	C_2H_5O. Per cent.
0.3934	0.1465	7.14
Calculated for the mono-ethyl ester,		8.50

Hydriodic acid, sp. gr. 1.96, was used in this determination.

The ethyl ester of tetrachlorgallein resembles the methyl ester very closely in appearance, solubilities and conduct

toward reagents. It shows the same marked basic properties as the methyl ester, combining with hydrochloric acid gas and dissolving in hot aqueous hydrochloric acid (sp. gr. 1.10) with a deep red color. Crystallized from benzene and dried to constant weight at 157°, it melted with decomposition at 275°–280°, but showed a marked contraction and softening at about 230°.

This ethyl ester was also prepared by boiling a mixture of anhydrous tetrachlorgallein (10 grams), absolute ethyl alcohol (100 cc.) and concentrated sulphuric acid (20 grams) for three hours. The crude product was crystallized from benzene once and dried to constant weight at 157°. Analysis:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.1853	13.83	26.47
Calculated for the ethyl ester,		26.76

An attempt was also made to prepare the ethyl ester by boiling the monopotassium salt of tetrachlorgallein with a mixture of ethyl iodide and absolute alcohol in a flask connected with a return condenser, but no reaction took place even after five hours and so the attempt was abandoned.

Tetrachlorgallein Trimethyl Ether.

A filtered solution of 25 grams of anhydrous tetrachlorgallein in one liter of absolute methyl alcohol was heated to boiling in a flask connected with a return condenser through which was added 75 grams of pure methyl iodide and then a solution of sodium methylate made by dissolving 9 grams of sodium in 250 cc. of absolute methyl alcohol. The mixture was kept boiling vigorously throughout the experiment so that there was no danger of oxidation, the air being excluded by the vapors from the boiling liquid. After a half hour the color of the solution changed gradually from blue to purple and then to deep red. At the end of 20 hours the solution was still alkaline and hence 20 grams of methyl iodide were added and the boiling continued until the reaction was no longer alkaline, about six hours being required. The deep

red solution was then concentrated to 100 cc. and poured into two liters of ether. This ethereal solution contained a considerable amount of partially methylated products soluble in alkali with a red color and these were removed by repeated extraction with a one per cent. sodium hydroxide solution. The ethereal solution was then used in obtaining the tetramethyl ether described in the following pages (see page 249).

The red alkaline extracts were united and the resulting solution heated to boiling, filtered, and acidified with dilute hydrochloric acid. The faintly yellow curdy precipitate which separated was filtered off, washed thoroughly with water, dissolved in ether,[1] and the filtered ethereal solution concentrated. After several hours a large amount of pale yellow crystals separated and these were filtered off and recrystallized from 94 per cent. ethyl alcohol. The product thus obtained was perfectly white, and melted at 253°–254° (uncor.). Recrystallization from 80 per cent. methyl alcohol and from 50 per cent. acetone did not change this melting point and so it seemed likely that the compound was pure. It was dried to constant weight in carbon dioxide at 110° and analyzed for chlorine with the following results:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2294	16.82	26.00
0.2189	16.11	26.10
Calculated for $C_{20}H_5O_7Cl_4(CH_3)_3$,		26.08
Calculated for $C_{20}H_6O_7Cl_4(CH_3)_2$,		26.76

The methoxyl content of this ether was determined by Mr. E. H. Nichols:

	Substance. Gram.	Silver iodide. Gram.	CH_3O. Per cent.
I	0.2985	0.4062	17.98
II	0.3196	0.4327	17.89
III	0.2882	0.3678	16.86
Calculated for the trimethyl ether,			17.11
Calculated for the dimethyl ether,			11.71

[1] Some of this product was insoluble in ether. It dissolved in one per cent. sodium hydroxide solution with a red color but the amount was too small to permit further investigation of the substance.

Nos. I and II were made with hydriodic acid of specific gravity 1.96 while III was made with the acid of specific gravity 1.7.

These analyses show clearly that the compound is the trimethyl ether of tetrachlorgallein. It is perfectly colorless and dissolves in ether, benzene and chloroform without color, while solutions in alcohol or acetone have a faint pink color. Like the trimethyl ether of gallein it resembles phenolphthalein very closely. It possesses fairly strong acid properties, reacting with sodium carbonate as well as with sodium hydroxide to form a sodium salt soluble in water with a red color.

Sodium and Ammonium Salts of the Trimethyl Ether of Tetrachlorgallein.

For the isolation of this sodium salt the following method was employed: An alcoholic solution of sodium hydroxide was added to a boiling alcoholic solution of the trimethyl ether, the proportions adopted being such that there was an excess of the trimethyl ether. The resulting deep red solution was then diluted with ether and the dark red precipitate formed filtered off, washed with ether, and dried to constant weight in hydrogen at 157°. The sodium in this salt was determined by decomposing a weighed portion of the substance with a measured excess of tenth-normal hydrochloric acid, filtering off the precipitated trimethyl ether, and titrating the excess of acid in the filtrate with tenth-normal sodium hydroxide solution, the trimethyl ether which remained in solution acting as the indicator.

Substance. Gram.	Tenth-normal hydrochloric acid. cc.	Sodium. Per cent.
0.4190	8.30	4.55
0.4634	8.80	4.37
Calculated for $C_{20}H_4O_7Cl_4(CH_3)_3Na$,		4.06

This sodium salt has a brick-red color and dissolves readily in water, alcohol and acetone with a red color, but is insoluble in ether, chloroform and benzene. When the red aqueous solution is acidified with hydrochloric acid, the color-

less trimethyl ether is precipitated. In one respect the trimethyl ether of tetrachlorgallein differs very markedly from phenolphthalein. Its dilute alkaline solution is not decolorized by the addition of strong alkalies or of alcohol. Indeed alcohol increases the color of such a solution. For this reason it may be used as an indicator for titrating alcoholic solutions. An excess of alkali or alkaline carbonates precipitates the sodium salt as an amorphous product resembling ferric hydroxide.

Further proof of the acid character of tetrachlorgallein trimethyl ether is found in its conduct toward dry ammonia gas. A weighed portion of the *colorless* trimethyl ether was placed in a current of ammonia gas carefully dried with soda-lime. It turned pink at once and came to constant weight after two hours, taking up exactly one molecule of ammonia, as shown by the following data:

Trimethyl ether.	Gain.	Ammonium salt of trimethyl ether.	Ammonia.
Gram.	Gram.	Gram.	Per cent.
0.1856	0.0055	0.1911	2.88
Calculated for $C_{20}H_5O_7Cl_4(CH_3)_3.NH_3$,			3.04

This *red* trimethyl ether monammonium salt was then placed in a current of air dried with calcium chloride. It lost ammonia slowly but completely, yielding the original weight of the *colorless* trimethyl ether.

Tetrachlorgallein Trimethyl Ether Hydrochloride.

Although tetrachlorgallein trimethyl ether has acid properties, yet it is also somewhat basic. It does not dissolve in hot aqueous hydrochloric acid (sp. gr. 1.10), but it does react with dry hydrochloric acid gas and forms a red hydrochloride showing a dull greenish luster. The amount of hydrochloric acid absorbed is a little greater than that calculated for one molecule, as shown in the following table:

Trimethyl ether.	Gain.	Trimethyl ether hydrochloride.	Hydrochloric acid.
Gram.	Gram.	Gram.	Per cent.
0.1636	0.0125	0.1761	7.10
Calculated for $C_{20}H_5O_7Cl_4(CH_3)_3.HCl$,			6.44

Nevertheless it is evident that a monohydrochloride is formed as with tetrachlorgallein itself and with its methyl

ester. The *red* trimethyl ether hydrochloride is perfectly stable in dry air at room temperature, but at 157° it is decomposed quantitatively into hydrochloric acid and the *colorless* trimethyl ether.

A method of making the trimethyl ether which is better than the one already described consists in cautiously adding dimethyl sulphate to a boiling solution of tetrachlorgallein in 2 per cent. alcoholic sodium hydroxide solution, oxidation being prevented by keeping the flask filled with hydrogen. The reaction is complete in about one hour and the yield of trimethyl ether is excellent. Its separation is accomplished as described in the case of the ether made from methyl iodide and an alkaline alcoholic solution of tetrachlorgallein.[1]

Tetrachlorgallein Trimethyl Ether Monacetate.

Although the trimethyl ether of tetrachlorgallein acts like a fairly strong acid, decomposing carbonates and combining with ammonia, still it seemed likely that it would react with acetic anhydride to form an acetate analogous to gallein trimethyl ether monacetate.[2] A mixture of 5 grams of pure trimethyl ether, 5 grams of sodium acetate and 25 grams of acetic anhydride was boiled for thirty minutes, when acetylation was complete, as shown by the fact that a test drop no longer gave a red color with sodium hydroxide solution. When this reaction mixture was poured into cold water, a brown oil separated which solidified after a short time to a yellow crystalline mass. This crude acetate was filtered off, washed with water, and crystallized from 80 per cent. alcohol. The product obtained in this manner was colorless and melted sharply at 221° (uncor.). It was dried to constant weight in carbon dioxide at 110° and analyzed for chlorine:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2113	14.30	24.00
0.2168	14.68	24.01
Calculated for $C_{20}H_4O_7Cl_4(CH_3)_3(C_2H_3O)$,		24.21

[1] Page 245.

[2] Orndorff and Brewer: This Journal, **26**, 136.

The properties of this compound are also in accord with the above formula. It is insoluble in cold aqueous alkalies, but boiling caustic soda solution dissolves it gradually with the red color characteristic of the trimethyl ether dissolved in alkali. In order to show that this acetate is really saponified, with the formation of the trimethyl ether, a small portion was boiled for two hours with a 2 per cent. solution of sodium hydroxide in methyl alcohol. The resulting solution was poured into cold water, an excess of hydrochloric acid added, and the pink precipitate formed was filtered off, washed with water, and crystallized from 80 per cent. alcohol. Colorless crystals were thus obtained which melted at 252°–254° (uncor.), and had the other properties of the trimethyl ether. They were dried to constant weight in carbon dioxide at 110° and analyzed:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2183	16.05	26.07
Calculated for the trimethyl ether,		26.08

Hence the tetrachlorgallein trimethyl ether monacetate is saponified by alkalies with the formation of the trimethyl ether.

Tetrachlorgallein Tetramethyl Ether (Colored).

The deep red ethereal solution from which the tetrachlorgallein trimethyl ether had been extracted with dilute sodium hydroxide solution[1] was thoroughly washed with water, filtered twice, and concentrated to a small volume. Dark red crystals formed gradually, and after about twenty hours these were filtered off, washed with ether, and recrystallized from ether. The crystals thus obtained melted at 217° (uncor.), and were red in transmitted light but dark green by reflected light. When this product was powdered by grinding, it lost the green color completely, and was then red by reflected as well as transmitted light. Chlorine and methoxyl determinations on this material, dried to constant weight at

[1] Page 245.

110°, showed that it was a tetramethyl ether of tetrachlorgallein:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2779	19.83	25.30
0.1953	13.99	25.40
Calculated for $C_{20}H_4O_7Cl_4(CH_3)_4$,		25.42
Calculated for $C_{20}H_5O_7Cl_4(CH_3)_3$,		26.08

Methoxyl determinations made by Mr. E. H. Nichols gave the following results:

	Wt. substance.	Wt. AgI.	CH_3O. Per cent.
I	0.2884	0.4943	22.65
II	0.3009	0.5110	22.44
Calculated for the trimethyl ether,			17.11
Calculated for the tetramethyl ether,			22.24

This red tetrachlorgallein tetramethyl ether is insoluble in water and in cold aqueous sodium hydroxide solution, but boiling aqueous alkali saponifies and dissolves it slowly with a red color. It dissolves readily with a red color in alcohol, ether, acetone, benzene, ethyl acetate and chloroform. The crystals from ether were examined by Professor A. C. Gill, of the Mineralogical Department of Cornell University, and his report is as follows:

"The crystals are either triclinic or monoclinic, probably the latter, since many show parallel extinction. Optical angle is small, pleochroism rather strong—deep red to yellowish red—and double refraction fairly high. The habitus of the crystals is stout columnar."

The fact that the tetrachlorgallein tetramethyl ether has a marked red color indicates that it is a quinoid compound and therefore similar in structure to the methyl and ethyl esters of tetrachlorgallein. Hence it seemed likely that the solubility of the red tetramethyl ether in hot alkali was due to saponification of the compound. To test the correctness of this view 2 grams of the pure red tetramethyl ether were boiled for two hours with 200 cc. of a 2 per cent. solution of sodium hydroxide in absolute methyl alcohol. The red

solution was diluted with water and acidified with hydrochloric acid. A faintly yellow precipitate was thrown down and the solution became colorless. This yellow precipitate was filtered off, washed with water, and crystallized from dilute alcohol. The resulting product was white, melted sharply at 253°–254° (uncor.), dissolved in alkali with a red color, and showed all the other properties of the colorless tetrachlorgallein trimethyl ether already described.[1] Analysis of this material dried to constant weight in hydrogen at 156° showed that it is really the tetrachlorgallein trimethyl ether:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2611	19.16	26.02
Calculated for the trimethyl ether,		26.08

Hence the red tetramethyl ether of tetrachlorgallein is really the monomethyl ester of the trimethyl ether. This was further shown by making the red tetramethyl ether by boiling the colorless trimethyl ether of tetrachlorgallein with a 3 per cent. solution of hydrochloric acid in absolute methyl alcohol.

The red tetrachlorgallein tetramethyl ether, like the tetrachlorgallein methyl ester of which it is a derivative, possesses basic properties. It dissolves in hot hydrochloric acid solution (sp. gr. 1.1) with a deep red color, and when the solid ether is exposed to the action of dry hydrochloric acid gas a red hydrochloride is formed. The amount of hydrochloric acid gas absorbed was much greater than that required for a monohydrochloride, but when this material was left in a current of dry air until it came to constant weight, the resulting product was the monohydrochloride of tetrachlorgallein tetramethyl ether, as shown by the following data:

Tetramethyl ether. Gram.	Net gain. Gram.	Tetramethyl ether hydrochloride. Gram.	Hydrochloric acid. Per cent.
0.4779	0.0319	0.5098	6.26
Calculated for $C_{20}H_4O_7Cl_4(CH_3)_4.HCl$,			6.14

[1] Page 244.

This hydrochloride is fairly stable in the air but is decomposed by hot water with the formation of hydrochloric acid and tetrachlorgallein tetramethyl ether.

Orndorff and Brewer[1] obtained not only a *colored* tetramethyl ether of *gallein*, but also a small amount of a *colorless* tetramethyl ether. Tetrachlorgallein, however, gave only the colored tetramethyl ether described above. It seemed likely that this colored tetramethyl ether might be transformed into a colorless tetramethyl ether by heating with solvents. Accordingly a solution of 2 grams of the red tetramethyl ether in 200 cc. of 70 per cent. ethyl alcohol was boiled for forty hours and then allowed to cool. The crystals which separated were examined under the microscope, and while there were a few stout columnar crystals of the red tetramethyl ether, still most of the material consisted of minute, almost *colorless* needles exactly like the crystals of the colorless gallein tetramethyl ether described by Orndorff and Brewer. These crystals were not soluble in boiling aqueous alkali nor were they saponified by alcoholic caustic soda, and hence could not have been either the tetrachlorgallein trimethyl ether or the red tetramethyl ether. The amount of material was entirely too small for an analysis but there can be no doubt, from the properties of the compound, that it was the *colorless* tetramethyl ether of tetrachlorgallein.

It is very likely that an alkaline solution of *gallein* also yields only the colored tetramethyl ether with methyl iodide and that the colorless tetramethyl ether obtained by Orndorff and Brewer resulted from a molecular rearrangement of the colored tetramethyl ether, especially as they purified this compound by crystallization from 50 per cent. alcohol and boiled the solution for some time with boneblack. In the case of tetrachlorgallein, there is no evidence of the formation of a colorless tetramethyl ether with methyl iodide or with dimethyl sulphate.

Tetrachlorgallein Dimethyl Ether Diacetate.

In one of the first attempts to make the tetrachlorgallein

[1] This Journal, **26**, 138.

tetramethyl ether by alkylation with methyl iodide, a white product was obtained which melted with decomposition at 253°–258° (uncor.). This material could not be purified by crystallization and so it was converted into an acetate by boiling with acetic anhydride and sodium acetate. The crude acetate was purified by crystallization from alcohol, dried to constant weight at 110°, and analyzed for chlorine:

Substance. Gram.	Tenth-normal silver nitrate. cc.	Chlorine. Per cent.
0.2345	15.49	23.39
0.2327	15.30	23.29
Calculated for $C_{20}H_4O_7Cl_4(CH_3)_2(C_2H_3O)_2$,		23.11

This compound is therefore the diacetate of a tetrachlorgallein dimethyl ether and its properties are in accord with this view. It is colorless, melts at 225° (uncor.), and is insoluble in cold caustic alkali though it dissolves in hot alkali, imparting a red color to the solution as saponification proceeds.

THEORETICAL.

The formula given to tetrachlorgallein by Graebe[1] is $C_{20}H_6O_7Cl_4$. In support of this formula he gives two analyses of the product precipitated from alcoholic solution by water and dried at 100°, and one analysis of this compound dried at 180°. From his analyses of the compound dried at 100° he deduces the formula $C_{20}H_6O_7Cl_4.2H_2O$, and for the product dried at 180° the formula $C_{20}H_6O_7Cl_4$. Graebe determined only carbon and hydrogen in his tetrachlorgallein, and as he probably dried the compound in air it was undoubtedly oxidized and impure. It is impossible, moreover, to decide between Graebe's formula and the formula $C_{20}H_8O_7Cl_4$ by determining carbon and hydrogen only. This is clearly shown in the following table:

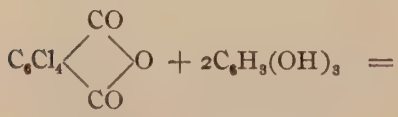
	Calculated for $C_{20}H_6O_7Cl_4$. Per cent.	Calculated for $C_{20}H_8O_7Cl_4$. Per cent.	Found by Graebe. Per cent.
Carbon.....	48.01	47.82	48.41
Hydrogen.....	1.21	1.61	1.89

[1] Ann. Chem. (Liebig), **238**, 337 (1881).

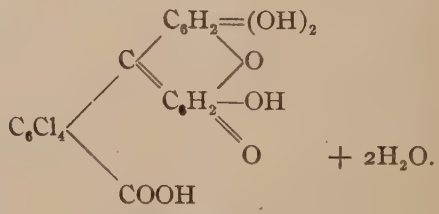
It is quite evident, therefore, that in assigning the above formula to tetrachlorgallein, Graebe simply took the formula for gallein, $C_{20}H_{10}O_7$, given by Buchka,[1] and substituted four chlorine atoms for four of the hydrogen atoms. This is also shown in Graebe's formula for the acetate, $C_{20}H_4O_7Cl_4(C_2H_3O)_4$, which is plainly derived from Buchka's formula for gallein tetracetate, $C_{20}H_8O_7(C_2H_3O)_4$, in the same way. Moreover, the percentages of carbon, hydrogen and chlorine found by Graebe for this acetate do not agree at all well with those required by the above formula.

The work of Orndorff and Brewer,[2] however, has shown that the formula given by Buchka for gallein is not correct and establishes the formula $C_{20}H_{12}O_7$ for this compound. The present investigation proves that tetrachlorgallein has the formula $C_{20}H_8O_7Cl_4$, and hence confirms the formula for gallein given by Orndorff and Brewer. It also proves that the formula for the hydrate is not $C_{20}H_6O_7Cl_4.2H_2O$, as given by Graebe, but $C_{20}H_8O_7Cl_4.H_2O$, analogous to that of gallein hydrate, $C_{20}H_{12}O_7.H_2O$. The formula $C_{20}H_8O_7Cl_4$ is the logical one to assign to tetrachlorgallein from its analogy to fluorescein, both as to its properties and the method by which it is prepared.

The formation of tetrachlorgallein may be represented by the following equation:



Tetrachlorphthalic anhydride. Pyrogallol.

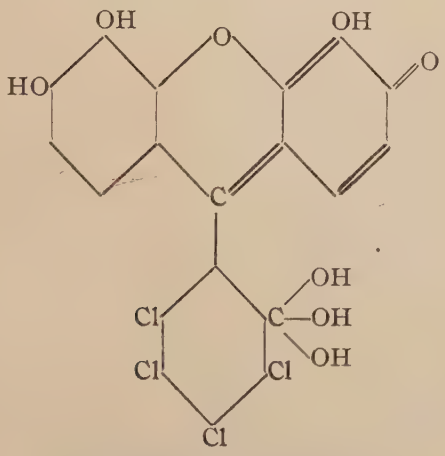


Tetrachlorgallein.

[1] Ann. Chem. (Liebig), **209**, 251.

[2] This Journal, **26**, 97 (1901).

The crude product obtained after removal of the zinc chloride is the monohydrate, and the same compound results from the metallic salts of tetrachlorgallein when they are decomposed with acids. As this hydrate is a *colored* compound which decomposes carbonates and acetates to form salts and combines with alcohols to form esters, it probably is a quinoid compound as well as an acid and must therefore be represented by the structural formula

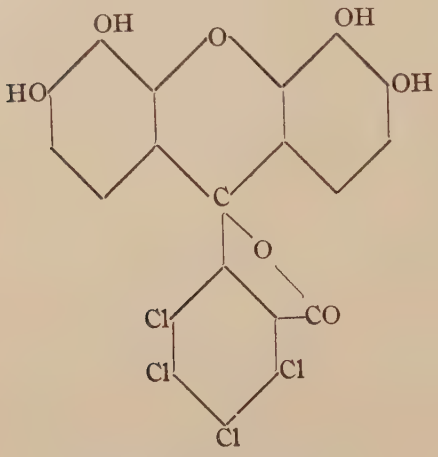


Tetrachlorgallein monohydrate.

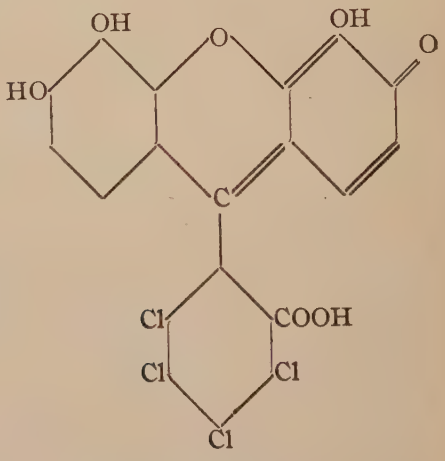
The extra molecule of water which the compound contains is here represented as water of constitution rather than as water of crystallization for the reason that it cannot be driven off completely until a temperature of 157° is reached and because tetrachlorphthalic acid itself contains a half molecule of water which must be regarded as water of constitution. In this connection it may be well to note that both the monosodium and monopotassium salts persistently retain a half molecule of water until they are heated to 157°.

The anhydrous tetrachlorgallein made from the monohydrate and also from the crude product crystallized from methyl alcohol, by heating to 157°, has only a faint pink color and therefore is the lactoid form of tetrachlorgallein

(I), or at any rate a mixture of this form with a small amount of the quinoid modification (II).



I. Lactoid form, colorless.



II. Quinoid form, colored.

Tetrachlorgallein.

Derivatives of both these tautomeric modifications have been made and analyzed. The tetrachlorgallein tetracetate,

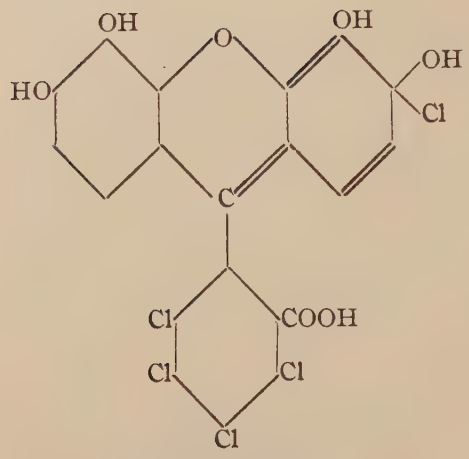
tetraphenylcarbamate, the tetramethyl ether not saponified by alkalies, the trimethyl ether and its acetate, are all colorless compounds and must hence be derivatives of the lactoid form (I). The metallic and ammonium salts, the esters and their hydrochlorides, the tetramethyl ether saponified by alkalies and its hydrochloride, the sodium and ammonium salts and the hydrochloride of the colorless trimethyl ether, the hydrochloride and the monohydrate of tetrachlorgallein itself, are all highly colored compounds and must therefore be regarded as derived from the quinoid form of tetrachlorgallein (II).

Tetrachlorgallein is then completely analogous to gallein. Gallein itself, according to Heller and Langkopf,[1] forms a hydrate, $C_{20}H_{12}O_7.H_2O$, having a reddish brown color, and as this substance does not lose its water completely until 180° and acts as an acid, it seems probable that it has a structure like that assigned to tetrachlorgallein hydrate.[2]

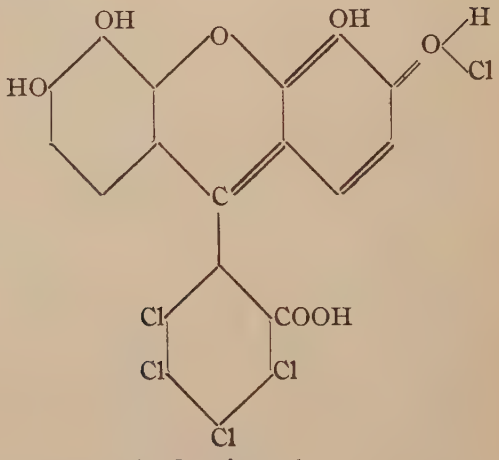
The introduction of the four chlorine atoms into the phthalic acid residue of gallein increases its acid and decreases its basic properties. That is, tetrachlorgallein is a stronger acid and a weaker base than gallein. This is shown very clearly by the fact that gallein itself dissolves readily in hot aqueous hydrochloric acid (sp. gr. 1.10) and the hydrochloride crystallizes from the filtrate, while tetrachlorgallein is insoluble in this hydrochloric acid and a hydrochloride cannot be obtained under these conditions. Tetrachlorgallein still possesses basic properties, however, since it forms a red hydrochloride when brought into contact, in the solid state or in solution in acetone, with dry hydrochloric acid gas. The esters of tetrachlorgallein, the colored tetramethyl ether (which is really a methyl ester of the trimethyl ether) and the colorless trimethyl ether also form red hydrochlorides very readily. These hydrochlorides may be regarded either as carbonium or oxonium salts, as shown in the formulas (I) and (II):

[1] Z. Farb. Ind., **5**, 115; Inaugural Dissertation, Ueber Mineral Salze der Phthaleinreihe, 30.

[2] Page 255.



I. Carbonium salt.

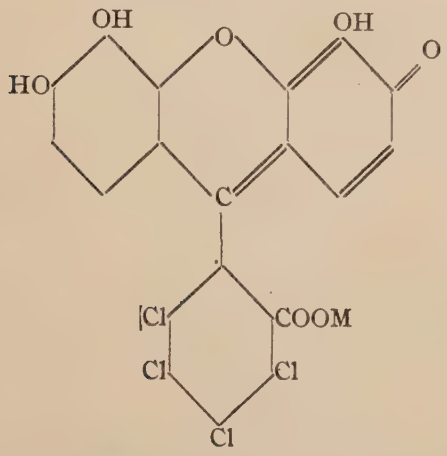


II. Oxonium salt.

Tetrachlorgallein hydrochloride.

It is interesting to note that the methyl and ethyl esters of tetrachlorgallein dissolve in hot aqueous hydrochloric acid (sp. gr. 1.10) and the hydrochlorides may be obtained from the filtrate in crystalline form.

The structural formulas of the monosodium and monopotassium salts and of the methyl and ethyl esters are represented as follows:

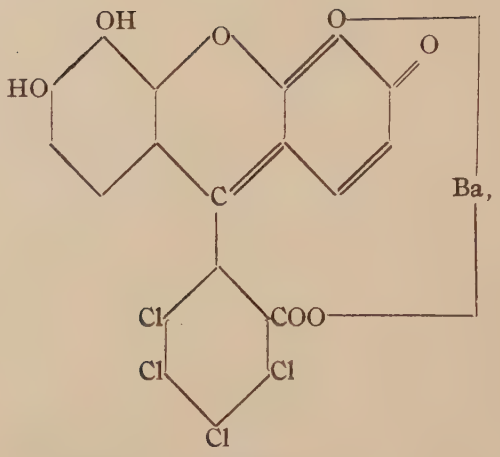


Alkali salts and esters of tetrachlorgallein.
(M represents Na, K, CH_3 or C_2H_5.)

The fact that tetrachlorgallein forms esters so readily by the ordinary catalytic method of esterification is worthy of note, since it forms an exception to the Victor Meyer rule[1] that substituents in both positions ortho to the carboxyl group inhibit the formation of esters by the ordinary catalytic method. The trimethyl ether of tetrachlorgallein also forms an ester by the ordinary method of esterification. In this respect tetrachlorgallein differs from its isomer, oxyhydroquinonetetrachlorphthalein, which, according to Osorovitz,[2] does not form an ester by the catalytic method.

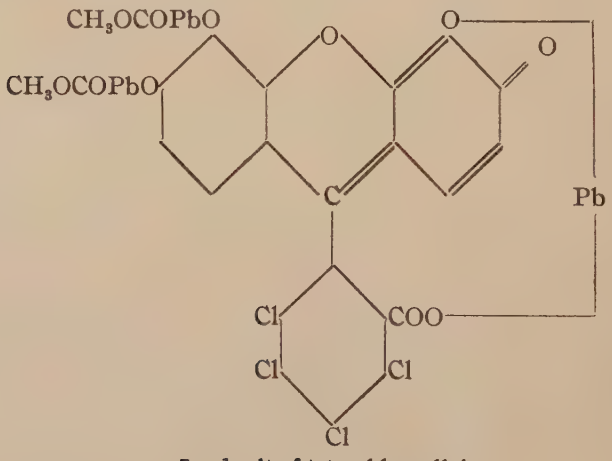
In the barium salt there is present one atom of barium to four atoms of chlorine, and hence two of the hydrogen atoms (one in the carboxyl group and one in one of the hydroxyl groups) must be replaced by barium. As the hydroxyl group in the quinoid ring would probably be more acid than the other hydroxyl groups, the barium salt would probably have the structure

[1] Ber. d. chem. Ges., **27**, 510, 1580 and 3146. See also Rosanoff and Prager: J. Am. Chem. Soc., **30**, 1895.
[2] Ber. d. chem. Ges., **36**, 1076 (1903).



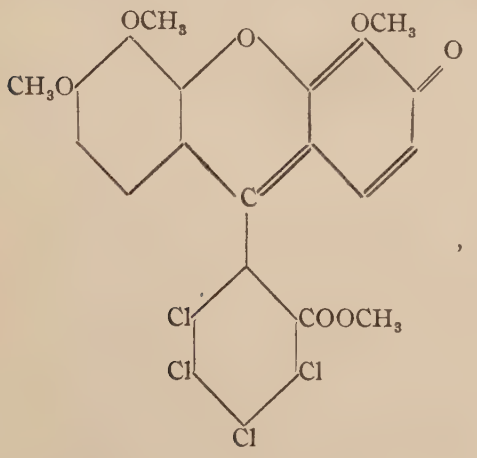
Barium salt of tetrachlorgallein.

and for the same reason the complex lead salt would have a similar formula:



Lead salt of tetrachlorgallein.

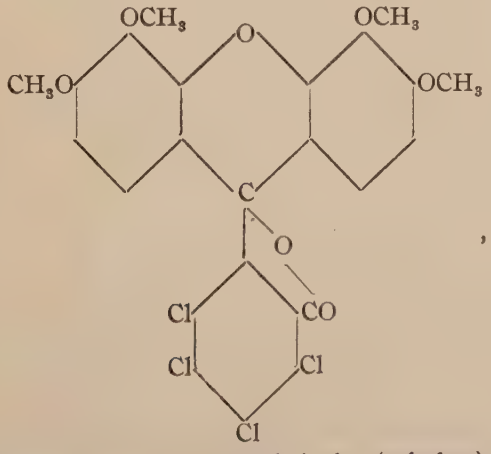
The red tetramethyl ether made by the action of methyl iodide or dimethyl sulphate on an alkaline solution of tetrachlorgallein, like the red tetramethyl ether of gallein, must have the quinoid structure as shown in the formula



Tetrachlorgallein tetramethyl ether (colored).

first, on account of its color; secondly, because, when saponified with alcoholic caustic soda, it yields the colorless trimethyl ether; and thirdly, because it can be made from the colorless trimethyl ether by the ordinary process of esterification.

The colorless tetramethyl ether which is formed from the above compound by simply boiling its alcoholic solution for a sufficient length of time, must have the lactoid structure

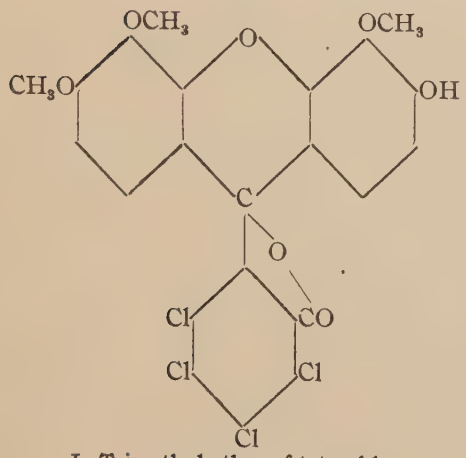


Tetrachlorgallein tetramethyl ether (colorless).

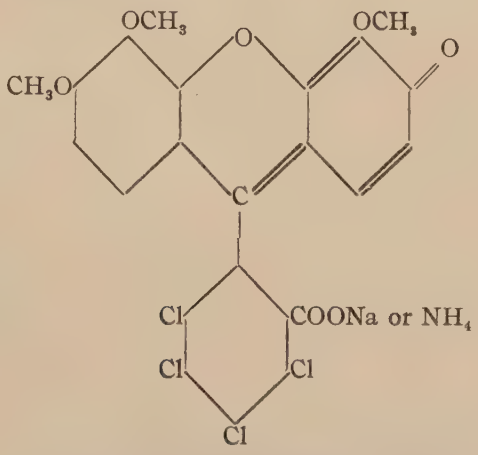
since it is insoluble in aqueous alkalies, has no color, and is not saponified by alcoholic caustic soda. The transformation of the colored into the colorless ether is strictly analogous to that observed in the case of the diethyl ether of phenolphthalein and of tetrabromphenolphthalein by R. Meyer and Marx,[1] though the change here takes place much less readily than in the cases mentioned by these authors. This easy change of the colored over into the colorless ethers by simply heating their solutions explains in a very satisfactory manner why in many cases the colorless ethers alone are obtained under conditions when the colored ethers are naturally to be expected, and also probably explains why Orndorff and Brewer[2] got both the colored and colorless tetra-ethers of gallein when they heated an alkaline solution of this substance in alcohol for a long time with an excess of methyl iodide. It seems highly probable, indeed, that colored ethers are first formed in all cases and then undergo molecular rearrangement into the colorless compounds.

The trimethyl ether prepared from tetrachlorgallein itself or from the colored tetramethyl ether by saponification is *colorless* and exactly analogous to the trimethyl ether of gallein, and hence the lactoid formula (I) is assigned to it, while the quinoid formula (II) best represents the structure of its red sodium and ammonium salts and shows the analogy of these salts to the red tetramethyl ether (see page 261):

[1] Ber. d. chem. Ges., **40**, 1437, 3603 (1907), and **41**, 2446 (1908).
[2] This Journal, **26**, 137 (1901).



I. Trimethyl ether of tetrachlorgallein (colorless).

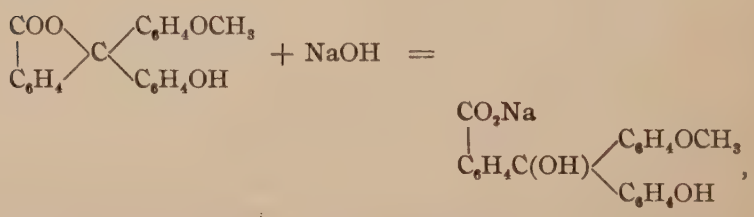


II. Sodium and ammonium salts of tetrachlorgallein trimethyl ether (colored).

The trimethyl ether is then tautomeric and resembles phenolphthalein very closely indeed. It reacts as an indicator exactly as phenolphthalein does. It yields a *colorless* monacetate and monomethyl ether (the colorless tetramethyl ether of tetrachlorgallein, see page 261), which must hence have the lactoid structure, and *colored* sodium and ammonium

salts (see II above), as well as a *colored* monomethyl ester (the colored tetramethyl ether of tetrachlorgallein, see page 261) having the quinoid structure.

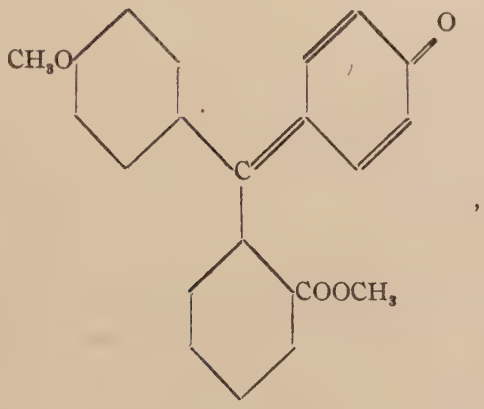
The fact that this colorless trimethyl ether forms colored salts and esters in exactly the same way that phenolphthalein does seems to be an insuperable objection to the oscillation theory recently advanced by Baeyer as an explanation of the color of the aniline and aurin dyestuffs (see page 205) and is in accord with the observation of Orndorff and Black[1] that the colorless monomethyl ether of phenoltetrachlorphthalein dissolves in alkalies with a red color. If this observation of Orndorff and Black should be confirmed it would form a further objection to Baeyer's oscillation theory mentioned above. The colorless monomethyl ether of phenolphthalein also dissolves in alkalies with a red color, according to R. Meyer and Spengler,[2] though this statement is disputed by Green and King,[3] who attribute the color to the presence of a small amount of phenolphthalein in the methyl ether. They are of the opinion that the ether is directly converted by alkalies into the colorless carbinol salt, as shown in the equation



and they cite the case of the colorless monomethyl ether of tetrabromphenolphthalein, which, according to Nietzki and Burckhardt,[4] also dissolves in dilute caustic alkalies without color. If these observations of Green and King and of Nietzki and Burckhardt should be substantiated they may be regarded as supporting Baeyer's theory of color, since there is no possi-

[1] This Journal, **41**, 377 (1909).
[2] Ber. d. chem. Ges., **38**, 1318 (1905).
[3] J. Soc. Chem. Ind., **27**, 6 (1908).
[4] Ber. d. chem. Ges., **30**, 178 (1897).

bility here of oscillation. Even granting this, however, the theory is not capable of explaining the color of such compounds as the methyl ester of phenolphthalein methyl ether made by Green and King,



or the colored diethyl ethers of phenolphthalein and of tetrabromphenolphthalein made by R. Meyer and Marx[1] unless it be assumed that the alkyl radicals can oscillate in the same manner as the metals. The colored tetramethyl ether of oxyhydroquinonetetrachlorphthalein[2] and the colored tetramethyl and tetraethyl ethers of gallein,[3] as well as the colored dialkyl ethers of fluorescein and eosin, are further examples of colored compounds which cannot be explained by Baeyer's theory.

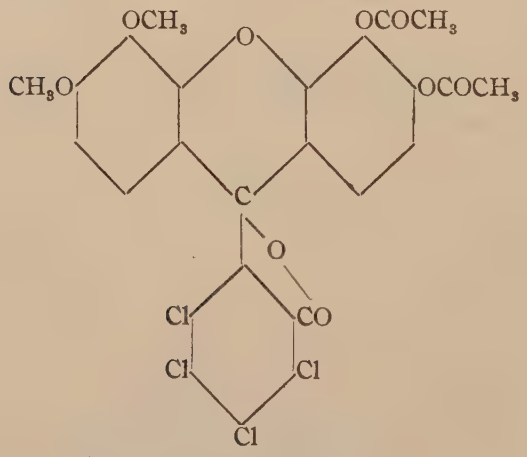
It may be well to emphasize here the interesting fact that the *colorless* trimethyl ether in the *solid state* takes up exactly one molecule of ammonia when placed in a current of dry ammonia gas and is converted into the *colored* monammonium salt. This salt loses all of its ammonia when placed in a current of dry air, leaving the colorless trimethyl ether unchanged (see page 247). This observation is similar to that made by Orndorff and Black[4] in the case of tetrabromphenol-

[1] Ber. d. chem. Ges., **40**, 1437, 3603 and **41**, 2446.
[2] Osorovitz: Ber. d. chem. Ges., **36**, 1076.
[3] Orndorff and Brewer: THIS JOURNAL, **26**, 97.
[4] THIS JOURNAL, **41**, 384 (1909).

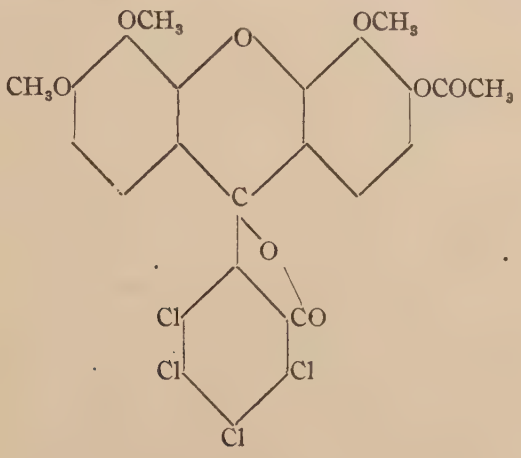
tetrachlorphthalein, which is *colorless* and in the *solid state* absorbs two molecules of ammonia to form the *blue* diammonium salt. On standing in the air this *blue* salt loses all of its ammonia and is transformed back again into the *colorless* phthalein. It is necessary, therefore, to assume that the change from the lactoid to the quinoid form and back again can take place in *solids* as well as in solution.

A similar change takes place when the *colorless* trimethyl ether of tetrachlorgallein in the *solid state* takes up hydrochloric acid gas, forming the *red* hydrochloride which loses all the hydrochloric acid when heated, thus yielding the *colorless* trimethyl ether again (see page 247).

The tetrachlorgallein dimethyl ether diacetate is also a colorless compound and must have the lactoid structure like the colorless trimethyl ether monacetate, as shown in the formulas

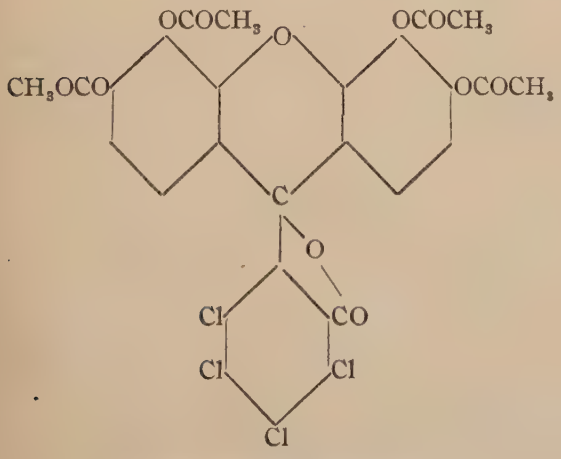


Tetrachlorgallein dimethyl ether diacetate.

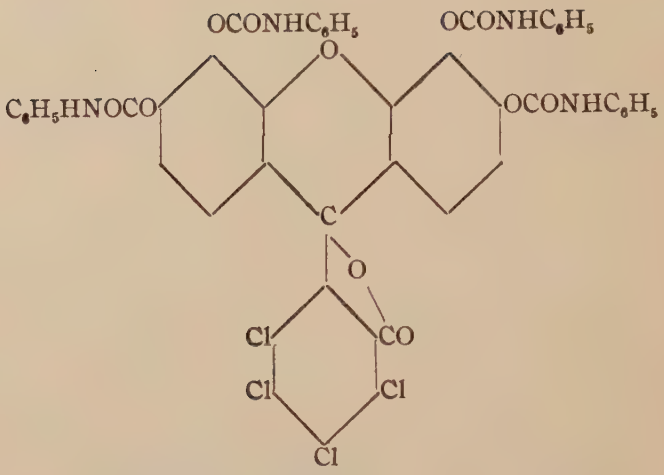


Tetrachlorgallein trimethyl ether monacetate.

The tetracetate and tetraphenylcarbamate are also colorless compounds and must hence be represented by the following lactoid formulas:



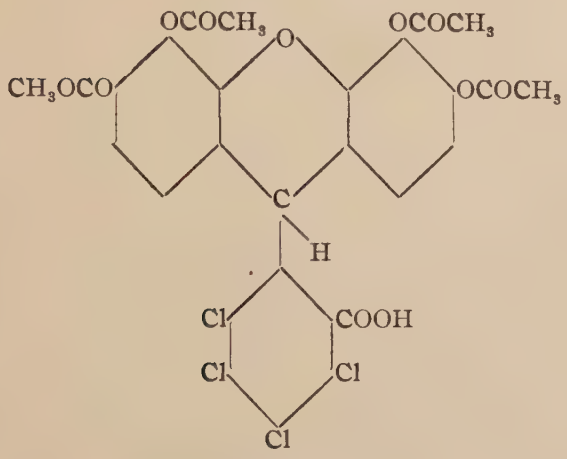
Tetrachlorgallein tetracetate.



Tetrachlorgallein tetraphenylcarbamate.

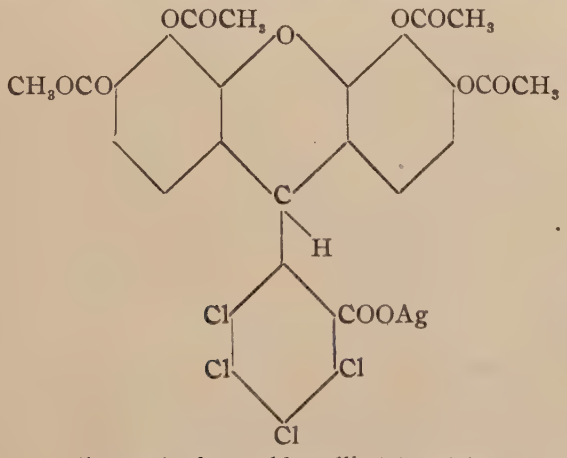
Orndorff and Brewer state that gallein forms a colored triphenylcarbamate. As they purified their compound by precipitation and determined the nitrogen by the Kjeldahl method, which in the case of the tetrachlorgallein compound was found not to give concordant results (see page 236), it is probable that this product was really a tetraphenylcarbamate. The color of the compound was light yellow and from the method of purifying it this may well have been due to the impurities. This is the only important point in which the results obtained by Orndorff and Brewer on gallein differ from those obtained on tetrachlorgallein, and as it seems highly probable that both substances would act exactly alike toward phenyl isocyanate and in the same manner as they do toward acetic anhydride, it is quite likely that a repetition of this work on gallein phenylcarbamate, by the same method as that used in making the tetrachlorgallein compound, would give a colorless tetraphenylcarbamate.

Tetrachlorgallin tetracetate results from the tetrachlorgallein tetracetate by the addition of two atoms of hydrogen and as it is a colorless compound and also an acid it must have the following structure:



Tetrachlorgallin tetracetate.

In accord with this formula is the fact that the substance dissolves in sodium carbonate solution, setting free carbon dioxide, and also forms a crystalline stable silver salt,



Silver salt of tetrachlorgallin tetracetate.

The existence of these two substances establishes the presence of four phenol hydroxyl groups and one carboxyl group in the molecule of tetrachlorgallin and confirms the formula for gallin established by Orndorff and Brewer.

SUMMARY.

The results of this investigation may be briefly stated as follows:

(1) Tetrachlorgallein is completely analogous to gallein. Its formula is $C_{20}H_8O_7Cl_4$ and that of its hydrate is $C_{20}H_8O_7Cl_4.H_2O$.

(2) Tetrachlorgallein contains a carboxyl group as is shown by its forming ammonium, sodium, potassium, barium and lead salts and methyl and ethyl esters. These compounds are all colored and must therefore have the quinoid structure. Tetrachlorgallein hydrate is also a colored substance and is hence to be represented as a quinoid compound. The anhydrous tetrachlorgallein, on the other hand, is so slightly colored that it probably has the lactoid structure or is a mixture of the lactoid compound with a small amount of the quinoid modification.

(3) The formation of a colored tetramethyl ether which, on saponification, yields a colorless trimethyl ether indicates the presence of three phenol hydroxyl groups and a carboxyl group in the molecule of tetrachlorgallein.

(4) Tetrachlorgallein, like gallein, is a tautomeric compound. In addition to the above-mentioned colored derivatives having the quinoid structure, it gives colorless compounds such as the tetracetate, the tetraphenylcarbamate, the colorless tetramethyl ether, the trimethyl ether and its acetate and the dimethyl ether diacetate, to which the lactoid formula must be assigned. The formation of these compounds indicates the presence of four phenol hydroxyl groups in the lactoid modification of tetrachlorgallein.

(5) A colorless trimethyl ether of tetrachlorgallein has been made. This substance is also tautomeric. It yields a colorless monacetate and monomethyl ether, and colored sodium and ammonium salts, as well as a colored methyl ester. The formation of these colored substances seems an insuperable objection to Baeyer's oscillation theory of the cause of color in the aniline and aurin dyes. The colorless trimethyl ether in the *solid state* combines with both ammonia and with hydrochloric acid to form *colored* compounds which

revert to the colorless ether in the air or on heating. This necessitates the assumption that the transformation from the lactoid into the quinoid condition and back again can take place in *solids* as well as in solution.

(6) Tetrachlorgallein is basic as well as acid, though not so basic as gallein itself. It combines with hydrochloric acid to form a red hydrochloride, and its esters (including the colored tetramethyl ether), as well as the colorless trimethyl ether, combine even more readily with this acid.

(7) Reduction of tetrachlorgallein tetracetate with nascent hydrogen yields the colorless tetrachlorgallin tetracetate, which has acid properties and gives a silver salt. Hence tetrachlorgallin must contain four phenol hydroxyl groups and one carboxyl group. This work confirms the formula for gallin established by Orndorff and Brewer.

(8) Tetrachlorgallein and its trimethyl ether form esters by the ordinary catalytic method of esterification and hence are exceptions to the Victor Meyer rule that compounds containing two substituents ortho to a carboxyl group do not form esters by the catalytic method or only form them with great difficulty. In this respect tetrachlorgallein differs markedly from its isomer, oxyhydroquinonetetrachlorphthalein, which, according to Osorovitz, does not form an ester by the catalytic method.

Another paper on tetrachlorgallein will be published in THIS JOURNAL in the near future.

CORNELL UNIVERSITY,
June, 1909.